Development of Mitigation Options for Bison-Vehicle Collisions on US 191

by

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ABSTRACT

Bison-vehicle collisions (BVCs) are a serious traffic safety concern on US 191 just north of West Yellowstone, Montana. The convergence of a high-traffic roadway with bison migratory paths makes this section of highway a prime location for these collisions to occur. This study provides mitigation recommendations for BVCs on this specific stretch of roadway. Previously collected crash and carcass removal data were analyzed for times and locations that had high numbers of BVCs. A survey was distributed to stakeholders to gather opinions and information on BVCs. Cost-benefit analyses were performed to assess the economic viability of mitigation measures given the rate of BVCs. It was found that the late winter and early spring months have the highest levels of collisions, and that BVCs have been increasing on US 191 for the past decade. Miles 2.5-4.5 and 7.0-9.0 on US 191 north of West Yellowstone were found to be BVC hot zones. Survey responses showed that participants believed the biggest contributing factors to BVCs were limited visibility and speeding, and that the most effective mitigation options would be wildlife fencing in combination with safe crossing opportunities, maximum speed limit reduction, and public education. The survey responses also assigned the majority of responsibility for mitigation funding to the federal government. Conservative cost-benefit analyses revealed that most mitigation options did not generate benefits in excess of costs, but this may change if passive use values such as the value of viable, migrating bison populations and ecological integrity parameters are included in the analyses. The researchers recommend that the traffic safety threat posed by BVCs would best be reduced by implementing an overpass with fencing and jumpouts, an animal detection system with fencing and jumpouts, or wildlife warning signage along with speed limit reduction enforcement at miles 2.5-4.5, and by an animal detection system with fencing and jumpouts or wildlife warning signage and speed limit enforcement at miles 7.0-9.0.

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1. INTRODUCTION

The United States has an expansive, complex system of roadways that serve to connect human communities in every corner of the country. As these roadways connect human habitat, they cut through wildlife habitat and migratory paths. When human and animal pathways intersect, wildlife-vehicle collisions (WVCs) occur. Each year, an estimated one to two million WVCs occur in the United States. These collisions are often dangerous to motorists. An average of 211 fatalities and 29,000 injuries occur each year as a result of WVCs (Huijser, et al., 2008). These collisions also have a significant economic impact as well. Huijser, et al. (2009) places the annual cost of WVCs at over eight billion dollars when taking into account the costs of property damage, medical attention, crash investigation by insurance companies and law enforcement, crash clean-up and carcass removal, and potential monetary value of animals killed in the collisions. WVCs are estimated to cause over a billion dollars in property damage alone each year (Huijser, Duffield, Ament, Clevenger, & McGowen, 2009).

Wildlife-vehicle collisions are a severe and often fatal problem for the animals involved; or rather WVCs are a possible consequence to the problems created by roadways. Roadways destroy, corrupt, and disconnect animal habitat. They disrupt and cut off migratory pathways. These effects can have huge impacts on species and ecosystems. WVCs are only one of the many negative effects of human transportation systems.

Bison-vehicle collisions (BVCs) are a unique type of WVC. The American bison (*Bison bison*) is the largest terrestrial animal in North America and lives in a herd. The massive size of bison and their tendencies to move in large groups can often result in vehicle collisions that are considerably more severe than those involving other types of wildlife. BVCs are also unique in their locations. There are only six regions in North America where bison are free-roaming: the Henry Mountains, Utah; Wind Cave National Park, South Dakota; Elk Island National Park and Wood Buffalo National Park in Alberta; Prince Albert National Park in Saskatchewan; and Yellowstone National Park, Wyoming/Montana. BVCs generally occur along roads in these parks and the surrounding regions.

The objective of this study is to examine bison-vehicle collisions along US 191 in the greater Yellowstone National Park region. US 191 from Bozeman, Montana to West Yellowstone, Montana is a notoriously perilous section of National Highway System. Running through the Gallatin River Canyon, US 191 has several traffic safety hazards, including limited visibility, lack of emergency turnout opportunities due to canyon walls and the Gallatin River, and a relatively high probability of WVCs. US 191 has high quality animal habitat on either side of the highway, which results in high levels of wildlife cross-traffic.

Bison are one of the many species whose habitat straddles US 191. Yellowstone National Park is home to the only genetically pure, continuously free-roaming herd of bison in the United States. Unfortunately, Yellowstone National Park only has suitable bison habitat for part of the year. During the winter and early spring, the bison leave the park to find easier grazing in lower elevations. One of the winter grazing grounds used by Yellowstone bison is the West Yellowstone basin. US 191 directly cuts through the bison migratory paths, which creates high levels of bison cross-traffic on the 10 mile stretch of US 191 just north of the town of West Yellowstone.

Unfortunately, bison presence along US 191 frequently results in BVCs. During one weekend in April, 2009, sixteen bison were killed in a total of five different collisions on this stretch of roadway. BVCs are severe and costly, and pose a very real threat to both motorist and bison safety.

This study seeks to provide mitigation recommendations for BVCs on US 191. Within recent years, there considerable progress has been made in mitigating WVCs. Due to the significant threat to traffic safety posed by large ungulates, specific attention has been paid to mitigating collisions with deer (*Odocoileus sp*.), elk (*Cervus elaphus*), and moose (*Alces alces*). Although many different types of mitigation measures have been described and implemented, only a few can reduce large ungulate vehicle collisions substantially. Unfortunately, due to the fact that bison-vehicle collisions only occur in a select few locations, there is very little experience and data on how to best mitigate collisions with bison. It is the hope of the researchers to identify mitigation measures that are best suited to reduce BVCs and provide safe crossing opportunities for specific segments of US 191.

2. BACKGROUND

It was necessary to perform background research on various aspects of bison-vehicle collision on US 191. Bison characteristics and behavior were examined to identify any obstacles in mitigating specifically for this species. Due to the controversial nature of bison presence in the West Yellowstone Basin, the management policies for the Yellowstone bison herd and the advocacy work surrounding them were researched. Mitigation measures that have been used in the past for bison and other large ungulates were researched to determine whether these measures might be considered for US 191. The findings from this background research are summarized in the following sections.

2.1. Bison Characteristics and Behavior

Information on bison behavior and physical build was gathered to better understand the applicability of various mitigation measures directed at other large ungulates to the mitigation of BVCs. Bison are the largest terrestrial animal in North America. They have an average weight of 1200-1800 lbs (544-816 kg), but can weigh up to 2000 lbs (907 kg) (Huffman, 2004). Bison also have the ability to jump up to six feet from a stand still position (Campaign M. o., 2010). Their coats are a very dark brown and the placement of their eyes does not reflect light well. This means bison on the roadway at night often are virtually invisible until it is much too late for the motorist to stop (Wildlife Vehicle Prevention Program, 2008).

Bison are herd creatures, and therefore travel in large groups. Even for relatively small groups of bull bison, it is unusual for them to travel in groups smaller than 18 bulls (Campaign M. 2., 2010). Mixed herds with cows and calves can consist of 100 individuals or more (Campaign M. 2., 2010). Bison are not necessarily afraid of people, cars, and roads. They often congregate on roads during winter to access early green-up roadside foraging and for the ease of travel the plowed roadways provide (Wildlife Vehicle Prevention Program, 2008).

2.2. Management of Yellowstone Bison

There has been much debate over bison presence in the state of Montana outside of Yellowstone National Park boundaries, particularly in the West Yellowstone and Gardiner basins. Bison carry a disease called brucellosis which causes bison to abort their fetuses. There is concern that bison may transfer this disease to cattle. However, elk are also known to carry the disease. Ironically, it was the cattle industry that originally introduced brucellosis in wild bison herds in the early 1900s. Should there be two cases of reported brucellosis-infected cattle within a certain time period, Montana's livestock would lose its brucellosis-free status. This can result in considerable economic damage to the state's cattle industry. Montana has only recently regained its brucellosis-free status, having lost it in September, 2008.

While there have never been any proven cases of bison transmitting brucellosis to cattle, bison are still believed to pose a threat to the security of Montana's cattle industry. As a result, bison presence on Montana lands is very strictly managed. In 2000, the Interagency Bison Management Plan (IBMP) brought together the Montana Department of Livestock (DOL), USDA -Animal and Plant Health Inspection Service (APHIS), USDA-Forest Service, National

Park Service, and Montana Fish, Wildlife, and Parks (FWP) with the hope to "maintain a wild, free-ranging population of bison and address the risk of brucellosis transmission to protect the economic interests and viability of the livestock industry in the state of Montana" (Interagency Bison Managment Plan, 2009).

The IBMP manages all bison in the state of Montana. The herd of bison that annually migrate out of Yellowstone National Park into the West Yellowstone basin falls under IBMP jurisdiction as soon as they leave the park. One-hundred bison are allowed within Zone 2 (

Figure 1) during part of the year. Should bison enter Zone 3 at any time, they are to be hazed back into Zone 2 by helicopters, all-terrain vehicles, and horseback riders. From November 15^{th} through February 15^{th}, bison are allowed to graze in Zone 2. Hunting of bison is allowed during this time. After February 15^{th}, the IBMP begins the process of hazing the bison out of Zone 2 and back into the boundaries of Yellowstone National Park (Zone 1). Throughout the spring, a series of hazing operations are conducted as necessary to push the bison back within park boundaries. In past years, the deadline for the end of bison presence in the West Yellowstone Basin has been May 15^{th}, one month before cattle are expected to enter the region for summer grazing (Interagency Bison Managment Plan, 2009). That date was pushed back to June 15^{th} this past spring.

The hazing routes of the IBMP follow the Madison River, on both the north and south sides, and along the northern border of Hebgen Lake down to Duck Creek (please refer to Figure 8) Just like the bison's natural migratory paths, these hazing routes intersect US 191. It was necessary to take these operations into account when evaluating mitigation measures for bison-vehicle collisions. Mitigation measures should not block off hazing route access, and crossing opportunities need to be able to handle large numbers of agitated bison.

In conducting this study, it was necessary to consider the implications of mitigating BVCs on a broader policy level in the context of the bison-livestock issue as described above. While there is a considerably large and vocal local support base for the bison, as well as regional and federal agencies working towards protecting the right of bison to access their natural habitat, bison presence in Montana is by no means seen as a positive occurrence by all stakeholders. The implementation of mitigation measures for bison-vehicle collisions would be sending the message that bison presence in Montana is expected and accepted. This is an important aspect of the mitigation of these collisions, and it was therefore necessary in this project to gather input from as many stakeholders as possible.

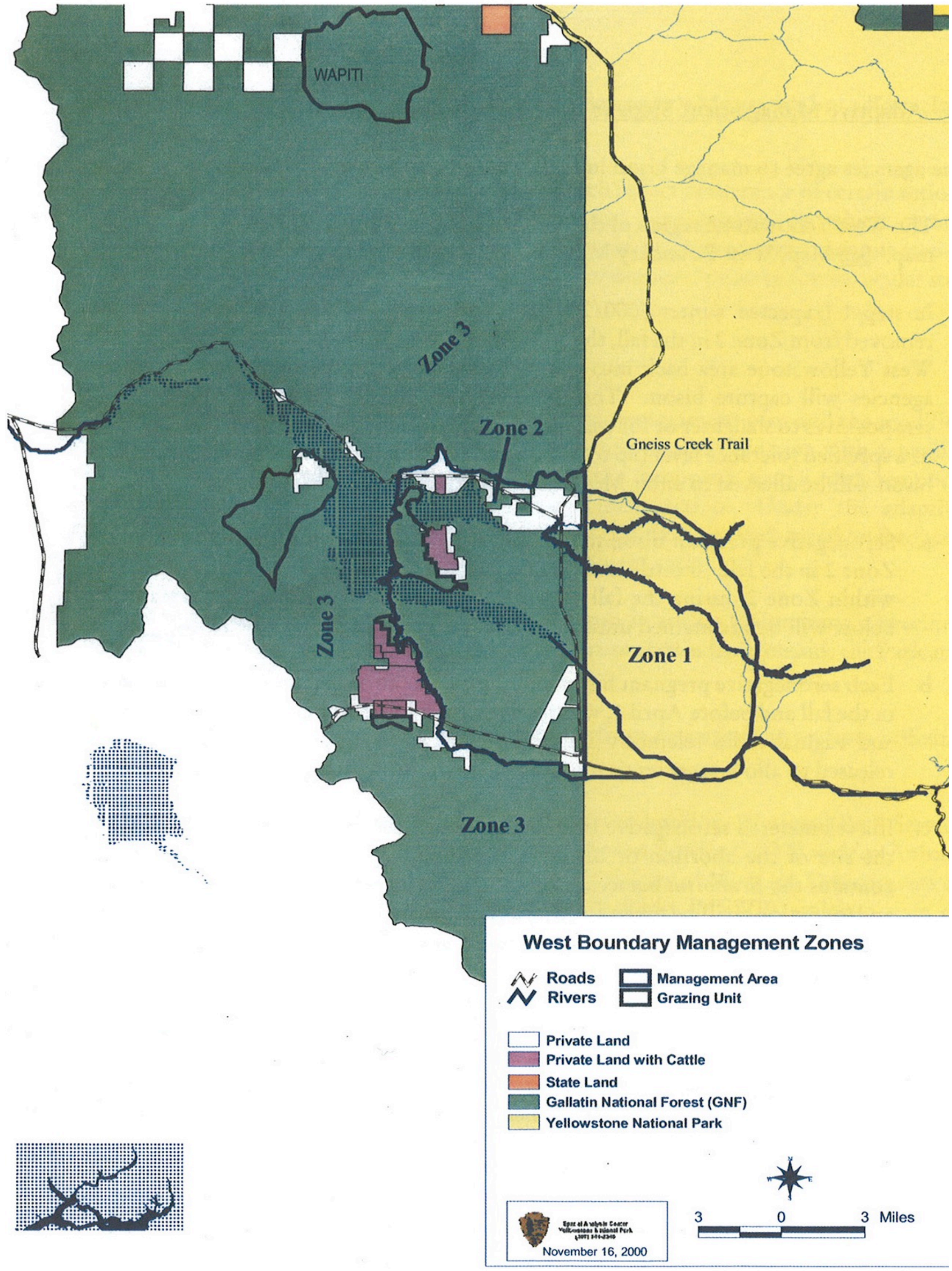


Figure 1: West Yellowstone Basin IBMP Management Zones
(Interagency Bison Managment Plan, 2009)

2.3. The Buffalo Field Campaign

The Buffalo Field Campaign (BFC) is a non-governmental organization dedicated to the protection of Yellowstone bison from bison management methods such as hazing. The members of the BFC run a year-round facility in the West Yellowstone basin that serves as a headquarters for the its daily field work in monitoring the movement and advocating the rights of the Yellowstone bison. The BFC has been monitoring the Yellowstone bison for the past 11 years, and has important information on not only the bison movements but also bison-vehicle collisions. BVC mitigation has been one of the BFC's main objectives for many years. BFC volunteers work as wildlife crossing guards for bison on US 191 when they are aware of bison proximity to the road. Their first hand experience with bison interaction with US 191 is a unique and crucial source of information on this issue.

2.4. Mitigation Measures Aimed at Large Ungulates

In recent years, WVCs have received increasing attention from both traffic safety and conservation perspectives. There has been special focus on vehicle collisions with large ungulates such as deer, elk, and moose. These animals pose a more severe and widespread traffic safety threat than other, smaller sized wildlife species. As a result, there have been extensive studies and implementation of mitigation measures addressed specifically for large ungulates.

Bison are also large ungulates, albeit the large ungulates in North America. It was hypothesized that many, if not all, of the mitigation measures that were effective for deer, elk, and moose would also be effective for mitigating bison-vehicle collisions. A review on mitigation measures that have proven to be effective for large ungulates was conducted to determine which of these mitigation measures might need special adaptations or were completely unsuitable for bison. Table 1 reports the estimated level of effectiveness for large mammals (Bison are not included in the term large mammals) for the mitigation measures initially considered by the researchers.

Table 1 also reports on which mitigation measures are believed to required modification should they be applied to bison. The majority of the modification needs stem from fencing issues. Bison would require special fencing that is stronger than the average wildlife fencing. This fencing would undoubtedly be higher in cost than average wildlife fencing. However, it would also be more durable and therefore have increased longevity.

Table 1: Comparison of Estimated Effectiveness of Mitigation Measures

Adapted from Wildlife-Vehicle Collision Reduction Study: Report to Congress (Huijser et al. 2008)

Mitigation measure	Estimated effectiveness (%)	Experimental (yes)	Best practice (yes)	Suitability for BVC Mitigation (modification required)
Seasonal wildlife warning signs	26.00%			
Animal detection systems (ADS)	82%	Yes	Yes*	
Fencing (including dig barrier)	87.00%		Yes	Modification required
Long bridges	100.00%			
Long tunnels or long bridges	100.00%			
Fence with gap and warning signs	0.00%			Modification required
Fence with gap and crosswalk	40.00%			Modification required
Fence with gap and ADS	82.00%	Yes	Yes	Modification required
Fence with underpasses	87.00%		Yes	Modification required
Fence with overpasses	87.00%		Yes	Modification required
Fence with under- and overpasses	87.00%		Yes	Modification required
Vegetation removal	38.00%	Yes	Yes*	Modification required
Roadway lighting	?		?	
Traffic calming techniques	?		?	

2.5. Mitigation Measures Aimed Specifically at Bison

Due to the differences in build, ability, and behavior between bison and other large ungulates, it is possible that some mitigation measures that have been effective at reducing collisions with deer, elk, and moose will prove ineffective at mitigating BVCs. Table 2 shows a comparison of the physical build of deer, elk, moose, and bison to demonstrate the difference between bison and other large ungulates.

Table 2: Comparison of Average Weight, Shoulder Height, and Body Length for Large Ungulates (Huffman, 2004), (National Geographic)

	Deer	Elk	Moose	Bison
Average Weight lbs. (kg)	130-280 (59-127)	325-1100 (147-499)	1200-1500 (544-680)	1200-1800 (544-816)
Average Shoulder Height ft. (m)	3.0-3.5 (0.94-1.07)	6.5 (1.98)	6.5-7.5 (1.98-2.29)	6.5 (1.98)
Average Body Length ft. (m)	4.5-7.0 (1.37-2.13)	4.0-5.0 (1.22-1.52)	8.5 (2.59)	12.5 (3.81)

Very few studies have been done on BVC mitigation in the United States because these collisions are only a traffic safety threat in very specific locations. In Canada, however, bison-vehicle collisions are better studied. The Wildlife Collision Prevention Program, administered by the British Columbia Conservation Foundation, has conducted a study of bison-vehicle collisions in Canada. This study lists several factors contributing to BVCs, including motorist travel speeds, poor visibility, and the prevalence of bison presence on the roadway due to the relatively easily accessible foraging and travel routes during the winter.

While this study does not list precise effectiveness percentages of each mitigation measure, it does give some valuable insight to how bison interact with certain mitigation measures. Exclusionary fencing was deemed an unrealistic mitigation option due to the large size and weight of bison and the extent of their range. Wildlife warning signage was also implemented, such as the one shown in Figure 2. The study acknowledges that signage proven to be ineffective at mitigating WVCs, but states that "jurisdictions do have a responsibility to notify drivers of hazards that they might encounter while driving" (Wildlife Vehicle Prevention Program, 2008).

A large variety of mitigation measures aimed at altering bison behavior and range were attempted, such as hazing, population culling, and population transfer. Very little feedback was provided in the report as to the effectiveness of these measures. Due to the lack of data, and the controversial management practices currently in use for the Yellowstone, the researchers have decided not to consider population management and relocation as possible mitigation measures for this study.

Figure 2: BVC warning poster used along the Alaska Highway (Public Works and Government Services Canada, 2008)

Various methods of vegetation management were also tested. Most were found to have little to no effect on bison behavior and proximity to the road. However, plowing trails parallel to the roadway was found to have some success at keeping bison off of the roadway itself. The cat trails provide bison with similar ease of winter foraging and travel routes as the highway itself, while keeping the bison out of traffic. While this method was "found effective" (no other information on the effectiveness of this mitigation measure is offered), it was only tried "with the Nordquist herd in winter 2007-2008" (Wildlife Vehicle Prevention Program, 2008). While it is encouraging to have previous, albeit limited, success with this mitigation measure at reducing BVCs, the lack of data and the small sample size means this method is still very much experimental.

3. METHODOLOGY

Temporal and spatial analyses were performed on mortality data for bison and other species to determine trends in crash rates over the years and seasons, and to identify high collision road segments. A cost-benefit analysis was performed to determine which mitigation measures would be economically feasible given the historical crash rates. A survey that collected the input of stakeholders was designed and distributed in accordance with Montana State University's Institutional Review Board's policies. The methods used to perform these tasks are described in the following sections.

3.1. Bison-Vehicle Collisions Data

Road mortality data for bison and other species were obtained for the 10-mile (16.09 km) long corridor along US Highway 191 between West Yellowstone and the border of Yellowstone National Park (north of Junction with US Highway 287) as well as for the stretch of US 191 that lies within park boundaries.

Data was acquired from the following sources:

Montana Department of Transportation (MDT)-Crash Data (1999-2008)

Montana Department of Transportation (MDT)-Carcass Removal Data (1999-2009)

Yellowstone National Park (YNP)-Gunther Roadkill-Carcass Removal Data (1980-2007)

In light of restrictions on construction in national parks, this study is focused on the part of US 191 in the area of interest that is under the jurisdiction of the Montana Department of Transportation (MDT). The different datasets were processed independently due to inconsistencies in recording and varying degree of accuracy of location. Crash and carcass removal data recorded by Montana Department of Transportation were combined to represent bison-vehicle collisions.

3.1.1. Data Error

The Montana Department of Transportation provided data points to the nearest tenth of a mile north along US 191 with West Yellowstone being the point of origin (milepost 0). Spatial accuracy of the given locations of the collisions is unknown, but referencing BVCs to the nearest mile segment in the spatial analysis was deemed sufficient refinement for this study.

Data on BVC occurrence may be underestimated. It has been reported that wildlife vehicle collisions may be underestimated, because not all collisions that occur are reported (Huijser et al 2008). Carcass removal data may be underestimated as some carcasses do not cause threat to human safety or a distraction to drivers, so are not removed or reported (Huijser et al. 2008). The percentage of unrecorded data is difficult to quantify, but it is important to note that the dataset used for this study is a minimum number based on actual numbers, and not an estimate.

Data Completeness

The crash and carcass removal data obtained from MDT is not comprehensive. The researchers were unable to obtain the crash data collected by MDT for 2009. There were only two duplicate collisions recorded in the crash data and the carcass removal data from 1999-2008, so it is likely that BVCs for 2009 are underrepresented in this study. Duplicates in datasets were determined by matching locations and dates of collisions.

3.1.2. Collisions vs. Bison Killed

It was necessary to distinguish in the data between collisions and bison killed. The crash data from MDT was given by collisions, which could sometimes have involved more than one bison hit. The carcass removal data was given by carcass, or bison killed. There could be several carcass recorded that would all belong to the same collision. The researchers chose to use collisions instead of bison killed for temporal and spatial analysis (the number of bison killed was analyzed in addition to the number of collisions in the temporal analysis to allow for comparison).The unit of collisions was believed to be more representative of the traffic safety threat that BVCs pose, whereas the unit of bison killed was thought to be more representative of a conservation view point. The carcass removal data was grouped into collisions when appropriate based on matching dates and locations. Duplicate collisions in the two datasets were removed. Many of the crash reports noted that there were other bison present on the roadway during the time of the collision. The researchers did not take the presence of other bison into account in the temporal, spatial, or economic analysis.

3.2. Data Analyses

3.2.1. Temporal Analysis

The bison-vehicle collision data, both crash and carcass removal, was compiled and analyzed for temporal trends. The graphing function in Excel was used to investigating whether there was a linear trend in annual BVCs. Excel was also used to investigate if the majority of BVCs were a seasonal occurrence. BVCs were grouped by month to same, also elsewhere in document the seasonal range of collisions.

3.2.1. Spatial Analysis

The crash and carcass removal data was converted into spatial layers by Geographic Information System (GIS) software, ArcGIS 9.3, using tools in ArcMap (Environmental Systems Research Institute 2009). The point files were merged together to form one file of BVC data.

The dataset examined in GIS was used to identify BVC clusters occurring along the ten-mile corridor on US 191. Spatial error was addressed by adding a buffering zone of a tenth of a mile to each BVC point. A hot-spot analysis was then performed on the buffered zones of the BVCs to show cluster areas.

3.2.2. Other Species

The crash and carcass removal data also included other species besides bison. The crash and carcass removal data for deer, elk, and moose were selected for analysis based on the cost data already available for these species in the *Cost–Benefit Analyses of Mitigation Measures Aimed at Reducing Collisions with Large Ungulates in the United States and Canada; a Decision Support Tool* by Huijser et al. 2009. Similar temporal analysis was performed for these species as for bison. Spatial analysis was not performed for deer, elk, and moose in GIS. Instead, Excel graphs were used to represent the location of vehicle collisions with these species. It was important to account for deer, elk, and moose as these species pose significant traffic safety and economic concerns. It would be beneficial if mitigation for bison could also include other large mammals, specifically deer, elk, and moose.

3.3. Cost-Benefit Analyses

Cost-benefit analyses were previously compared for mitigation measures aimed at reducing collisions with large ungulates, such as deer, elk, and moose (Huijser, et al. 2009). For this report, the costs and effectiveness of the mitigation measures and average BVC costs were modeled after the cost-benefit analyses developed by Huijser et al. (2009).

3.3.1. Mitigation Measures Costs and Effectiveness

Huijser et al. (2009) reviewed over 40 different mitigation measures, with 13 of these measures considered effective in reducing collisions with large animals. Ten of these measures were considered in this economic analysis (see Table 3: Present Value Costs for Mitigation Measures at 3% below), as culling, relocation, and infertility treatment were considered ineffective for this species. Costs and effectiveness for lighting, rumble strips, vegetation management, and variable message signs were not available, and were therefore not included in the cost-benefit analyses for this report.

Present (discounted) value costs were estimated (in 2009 US$ per mile) over a 75-year period for each mitigation measure (see Appendix 1 for description of mitigation measures costs). The mitigation measure costs included planning, installation, maintenance and operation, and removal. Real discount rates of 1%, 3%, and 7% were used to correct for the time value of money.

An amortized annual cost (in 2009 US$) was produced by multiplying the present (discounted) value cost by the amortization factor in a 75-year period for each mitigation measure. The amortization factor, also known as the uniform series capital recovery factor, is used to determine the value of a series of end-of-year costs (amortized annual cost). This annual cost can be associated with the benefit (in 2009 US$) each mitigation measure needs to generate in order to break even in a 75-year period.

The cost benefit of implementing a mitigation measure can be determined by comparing its annual costs with annual benefits realized (calculated as the effective reduction in the number of collisions multiplied by the cost per collision).

The effectiveness is related to the reduction of collisions. The effectiveness for each mitigation measure in this report is based on the effectiveness used in the cost-benefit analyses performed by Hiujser (et al 2009), in which a mean was calculated if more than one estimate was available. Additional studies evaluating the effectiveness of the mitigation measures may lead to variations of these values in the future.

Table 3 below lists the mitigation measures compared for this cost-benefit analysis. Each mitigation measure is described by effectiveness and present worth costs in 2009 US dollars per mile at a 3% discount rate.

Table 3: Present Value Costs for Mitigation Measures at 3%

Adapted from Cost-Benefit Analyses (Huijser, Duffield, Ament, Clevenger, & McGowen, 2009)

Mitigation Measures	Effectiveness	Present value costs at 3% (2009 US$)	Costs per percent reduction (US$)
Seasonal wildlife warning sign	26%	$3,860	$239
Fence, gap, crosswalk	40%	$414,078	$12,506
Fence (incl. dig barrier)	86%	$296,927	$3,625
Fence, underpass, jump-out	86%	$695,462	$10,420
Fence, overpass, jump-out	86%	$3,031,454	$13,932
Animal detection system (ADS)	87%	$1,137,520	$21,038
Fence, gap, ADS	87%	$968,311	$16,000
Elevated roadway	100%	$64,519,303	$1,537,566
Road tunnel	100%	$93,593,576	$2,463,200
Lighting	-	-	-
Rumble strips	-	-	-
Variable Message Signs	-	-	-

3.3.2. Cost Estimates for Bison-Vehicle Collisions

The total estimated costs for the average bison-vehicle are summarized in Table 4. There was no specific cost data available for bison-vehicle collision. Based on the similarity in weight and shoulder height (Table 2) cost estimates for moose were used for bison.

The researchers believe this cost substitution to be comparable to the actual average cost of a BVC. However, there are several unknowns that could have considerable effects on the total cost. As there is no data on the percent of BVC resulting in human injury and fatality, the percentages for moose-vehicle collisions were used. These percentages may not directly translate for several reasons. The bulk of a moose's weight is carried higher off the ground than bison; this could mean that there is a greater chance that a collision with a moose would result in the animal being thrown over the hood of the vehicle, through the windshield, and into the motorist. On the other hand, while bison carry the bulk of their weight much lower to the ground, BVCs are more likely to involve more than one individual animal because bison travel in herds, unlike moose.

The differences in mass of moose and bison likely result in differences in crash severity, and therefore the actual cost of a BVC. Crash severity is relatable to change in velocity of vehicle, which is expected to be greater when stationary object impacted has a greater mass. The mass of a bison is, on average, 20% greater than that of a moose. In theory, this would lead to greater change in velocity of vehicles involved in collisions with bison than collisions with moose, which would lead to more severe crashes. Further research is required to understand the extent of variation between the cost of moose-vehicle collisions and the actual cost of bison-vehicle collisions.

The hunting value and carcass removal fees are based on collisions involving only one animal. This is important to note, as the cost of a BVC collision could increase should there be more than one bison involved. 31% of the recorded BVCs of US 191 in the past decade involved more than one bison.

Table 4: Breakdown of Cost Estimates of Moose-Vehicle Collisions vs. Bison-Vehicle Collisions

(Highlighted values show adjustments made when data was available.)

	Moose	Bison
Vehicle Repair	$5,600.00	$5,600.00
Human Injuries	$10,807.00	$10,807.00
Human Fatalities	$13,366.00	$13,366.00
Towing/Accident Att.	$500.00	$500.00
Hunting Value	$387.00	**$1,800.00**
Carcass Fees	$100.00	**$150.00**
Total	**$30,760.00**	**$32,223.00**

3.4. Stakeholder Survey

3.4.1. Survey Design

Due to the sensitive nature of bison presence in Montana, and the implications of mitigating specifically for bison, a survey was designed to collect the opinions of different stakeholders. It was adapted from a survey that was written and used by Marcel Huijser to collect the opinions of locals on an animal detection system that was installed along US 191 within the Yellowstone National Park boundaries from 2000-2008. Due to the use of human subjects, it was required that the survey be submitted to and approved by the MSU-Bozeman Institutional Review Board. The majority of the questions were in multiple choice format to allow for easier response analysis, however there were three open response choices that allowed the participants more freedom to expand upon certain topics. In accordance with the Institutional Review Board requirements, the participants were given the option to answer with either “I do not know” or “I do not wish to answer this question” for every question.

The survey was comprised of two sections. Part I had a total of 25 questions and was directed at all survey participants. The questions in this section were designed to gather the opinions of the participants on the history and projected future of BVCs, the causes of the collisions, the effectiveness of possible mitigation measures, and the responsibility of funding these measures. Part II was directed specifically at participants who had direct experience handling or observing the West Yellowstone bison. The questions in this section sought to gather information on bison behavior along the roadside and bison management operations. The intent was to use information gathered from Part II as a direct tool in evaluating the potential effectiveness of possible mitigation measures. See Appendix 2 for the full survey.

3.4.2. Participant Selection

A broad base of participants was required for the survey feedback to accurately reflect the general feelings of the stakeholders. A total of 22 agencies and organizations were identified for possible participation based on their involvement with bison and bison-vehicle collisions. These entities represented a relatively even distribution in the categories of governmental agencies, natural resource management agencies, and non-governmental organization. For each agency, the researchers attempted to find the name and contact information of specific employees that were involved with bison or traffic control and maintenance of the West Yellowstone segment of US 191. This was not always possible due to the employee contact information made public by these agencies. The identity of individuals representing the selected agencies is kept confidential; only the organization represented is made public. The following is a list of the agencies contacted for survey participation.

Governmental agencies: Montana Department of Transportation, Montana Department of Transportation – Bozeman District, Montana Department of Livestock, State Highway Patrol, USDA- Animal and Plant Health Inspection Service (APHIS), Gallatin County Sheriff

Natural resource management agencies: Yellowstone National Park, Gallatin National Forest, Montana Fish Wildlife & Parks

Non-governmental: Buffalo Field Campaign, Defenders of Wildlife, Greater Yellowstone Coalition, Yellowstone Buffalo Foundation, Buffalo Allies of Bozeman, Horse Butte Neighbors of Buffalo, National Parks Conservation Association, Yellowstone Association, Western Watersheds Project, GravelBar

Other: Gallatin County Commissioner's Office, West Yellowstone City Councilors, Intertribal Bison Cooperative

3.4.3. Survey Administration Method

There were a couple of different methods used to administer the survey to the agencies. The survey was sent via mail or email to the selected agencies. When possible, the surveys were addressed to specific employees. A cover letter explaining the purpose of the survey, the process of participating in the study, and the participants' rights as research subjects was included with the survey. A findings request form was also included.

Follow-up calls were placed after allowing for enough time for the survey to reach potential participants. Potential participants were asked whether or not they would like to participate in the study. If they answered in the affirmative, they were given several choices in how to respond to the survey: fill out the survey and send it back to the researchers via email, mail, or fax, or schedule a time to give survey responses via an in-person or telephone interview. If a participant could not be immediately reached, a series of follow-up calls were placed in the hopes of a response.

4. FINDINGS

Data analysis revealed very strong temporal trends in BVCS for the past decade. Spatial analysis with ArcGIS identified high collision road segments. Cost-benefit analyses performed for these high collision areas determined which mitigation measures were economically justified given the historical collision data. Survey responses provided feedback on the expectations stakeholders have on the effectiveness of different potential mitigation measures, as well as the potential causes of BVCS and responsibility of mitigation funding. These findings are detailed in the following sections. The temporal, spatial, and cost-benefit analyses as well as the survey responses informed the mitigation recommendations listed in Section 4.5.

4.1. Temporal Trends

4.1.1. Annual BVC Distribution

Crash and carcass removal data were analyzed for temporal trends. Figure 3 shows that BVCs on US 191 have been increasing over the last decade. In 2005, there was a sharp increase in BVCs that continued through 2009. Due to the incompleteness of the data available to the researchers, this trend may not be 100% accurate. However, the trend suggested by the crash and carcass removal data is supported by the survey responses as presented in Section Responses to Part I4.4.1

There was no data for BVCs available to the researchers for the winter and spring of 2010. However, the BFC stated in a personal interview that due to their mitigation work as crossing guards and with warning signs, there were no BVCs on US 191 for 2010 thus far. The projected linear trend lines suggest that BVCs, if unmitigated, are a growing problem on US 191.

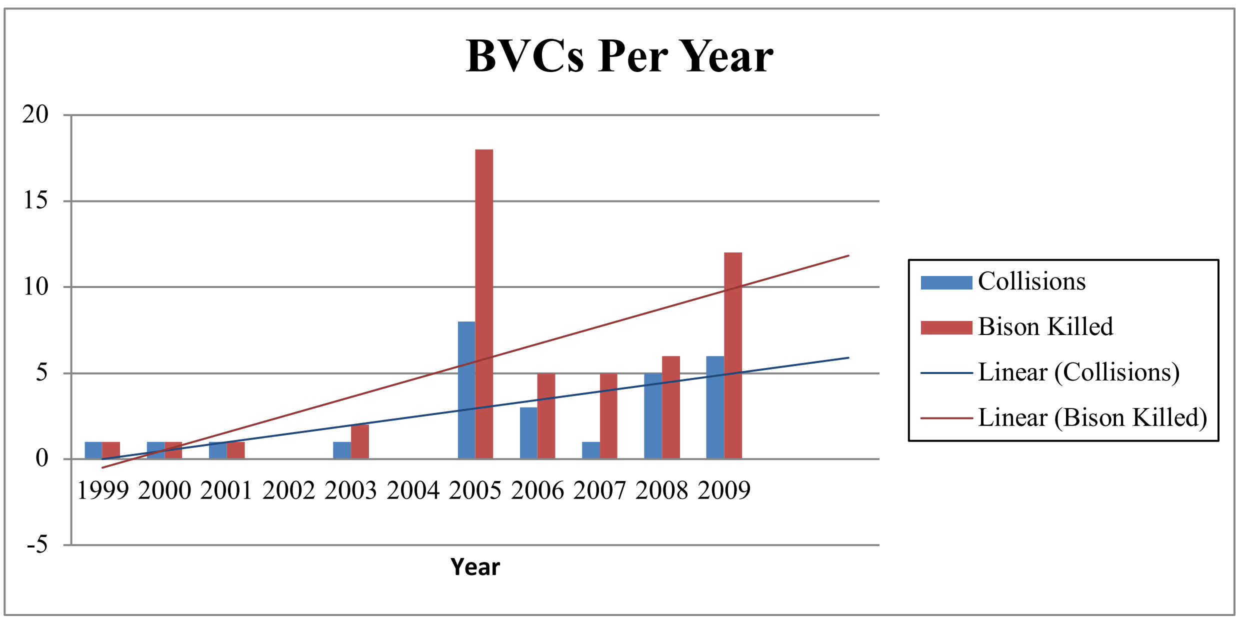


Figure 3: BVCs per year from 1999-2009, by collisions and by bison killed

4.1.2. Monthly BVC Distribution

Figure 4 shows the distribution of BVCs by month . The majority of BVCs occur in February through May. This is the time of year when bison presence in the West Yellowstone basin is the highest. Bison come down into the basin for more accessible winter grazing and for spring calving grounds. The outlier BVCs in November and December can likely be attributed to bull bison, which tend to have a wider range away from a herd. The sharp drop off in collisions in June is due to the Interagency Bison Management Plan. In past years, there has been a no tolerance policy for bison presence in the West Yellowstone basin after May 15th. However, this past spring the deadline for bison presence was extended to June 15th for future years. An extension in bison presence in the West Yellowstone Basin means an extension in the time period with a potential for BVCs.

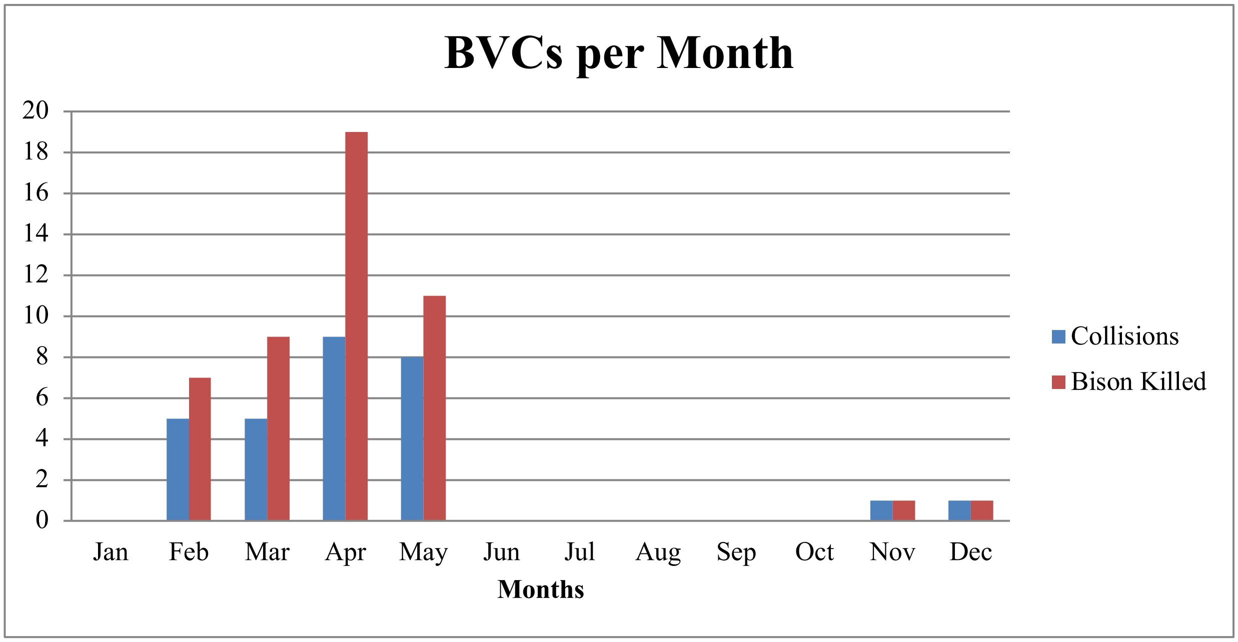


Figure 4: BVCs per month from 1999-2009, by collisions and by bison killed.

4.1.3. Temporal Trends for Other Large Ungulates

Very little overlap in temporal trends was found between BVCs and collisions with deer, elk, and moose. The high collision season for other large ungulates on US 191 appears to be from late summer to early fall (Figure 5).

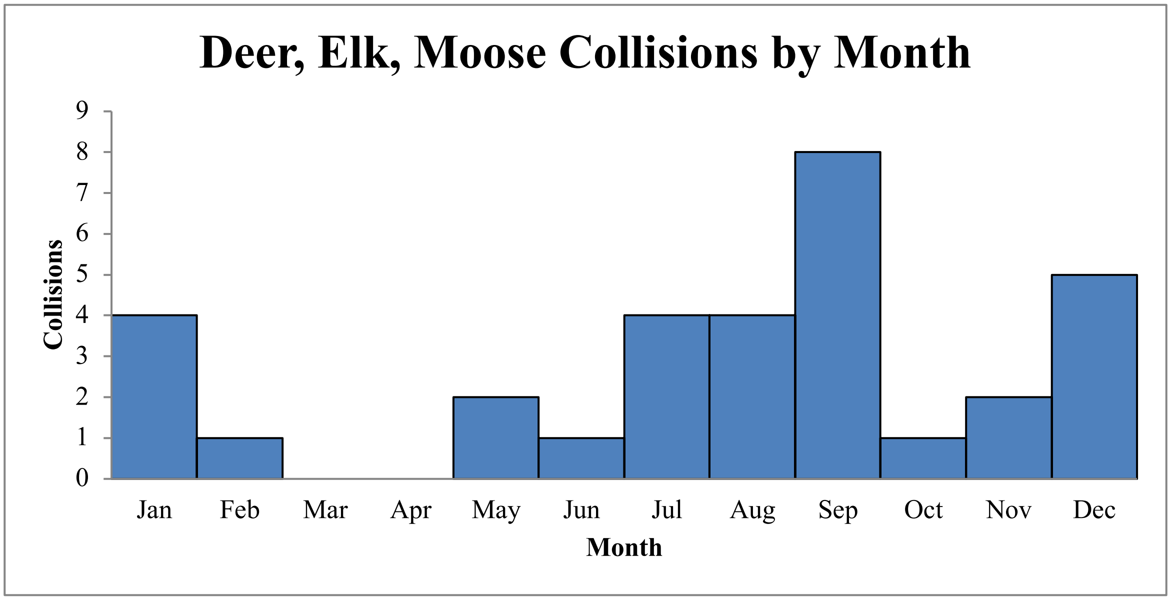


Figure 5: Monthly Distribution of Large Ungulate Vehicle Collisions on US 191 for the past decade.

These collisions also appear to have been experiencing a downward linear trend for the past decade, which is projected to continue based on the available data (Figure 6). No large ungulates besides bison were hit on miles 2.5-4.5 from 2005 to 2009. Collisions with deer, elk, and moose were not therefore considered for the cost-benefit analyses.

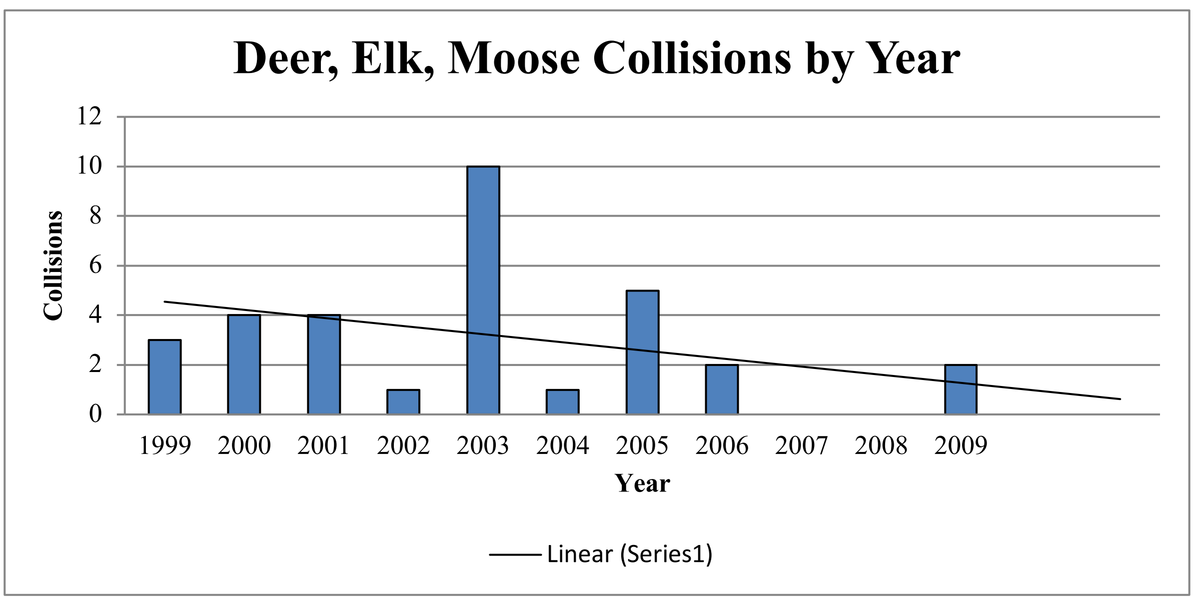


Figure 6: Large Ungulate Vehicle Collisions on US 191 for the past decade.

4.2. High Collision Areas

A hotspot analysis was performed (Figure 7) to show clusters of BVC points with similar locations in terms of miles north of West Yellowstone. A high Z score indicates a spatial clustering of high values (in terms of miles north of West Yellowstone), while a high negative Z score indicates a spatial clustering of low values. The higher (or lower) the Z score, the more intense the clustering. Clusters are shown around 3.5 and 8 miles north of West Yellowstone. These high collision areas are shown at points of intersection of the highway and natural migratory path of bison (along the waterways of Duck Creek and Madison River). For this study, these areas of high BVCs will be the focus for mitigation sites.

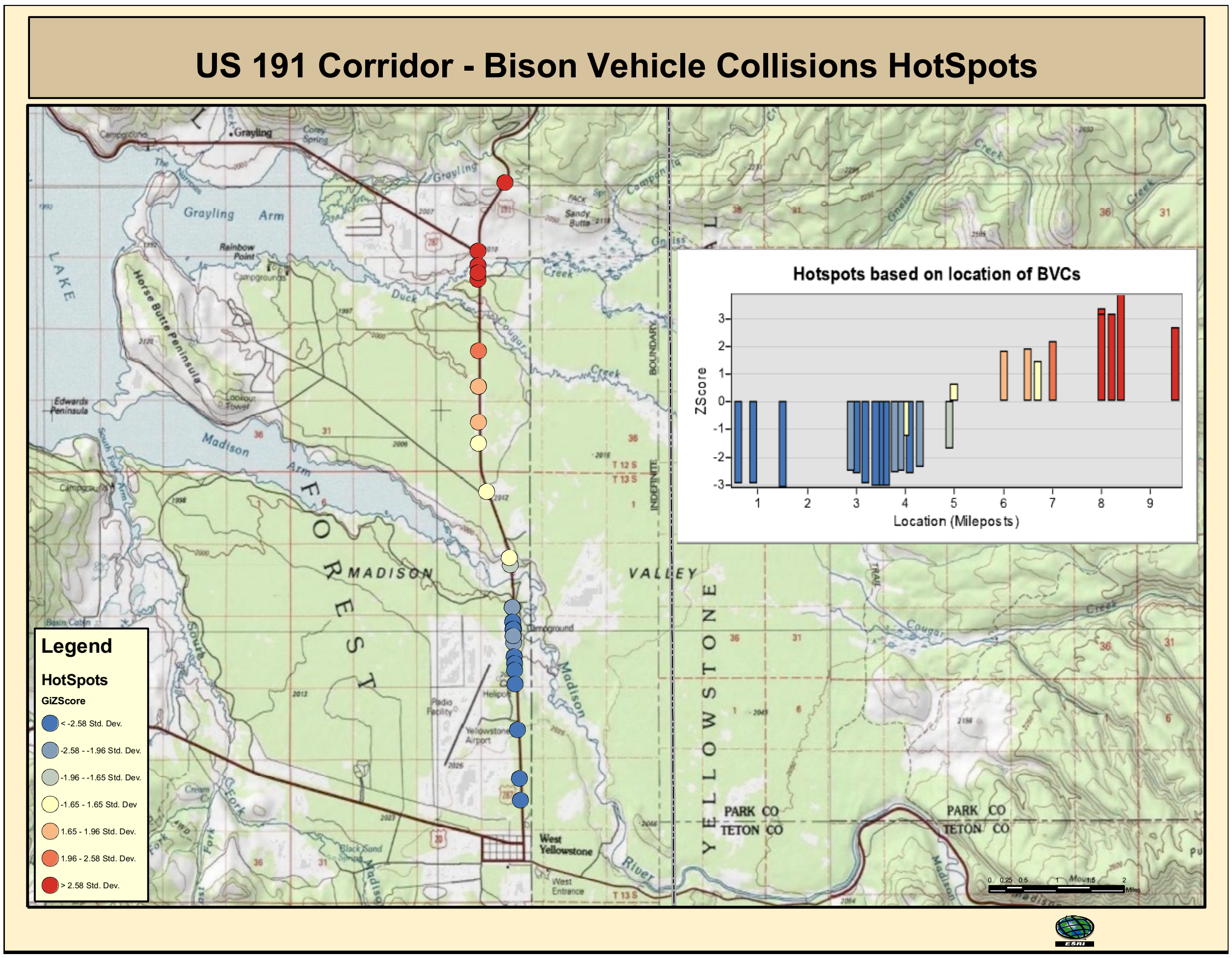
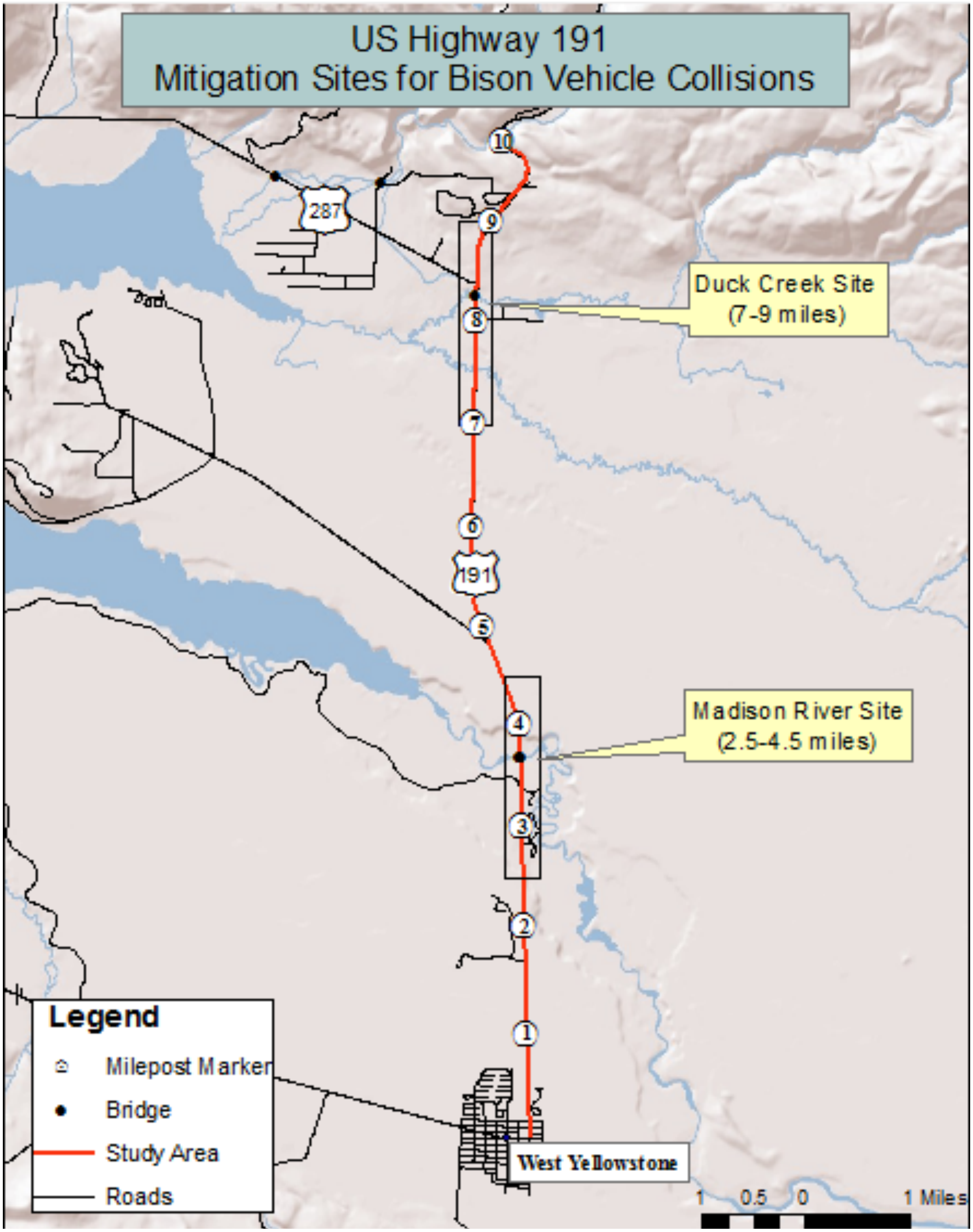


Figure 7: BVC high collision areas on US 191

Mitigation sites are defined around these locations with a mile of mitigation on both sides. Road segments between miles 2.5 and 4.5 north of West Yellowstone (Madison River), and between miles 7.0 and 9.0 (Duck Creek) were recommended as mitigation sites, as shown in Figure 8 below. The road segment between 2.5 to 4.5 at the Madison River mitigation site includes 2 miles (3.22 km) of very high BVC rates, representing only 20% of the total highway segment under study and 51% of the total BVCs.


US Highway 191
Mitigation Sites for Bison Vehicle Collisions
Duck Creek Site
(7-9 miles)
Madison River Site
(2.5-4.5 miles)
287
191
10
9
8
7
6
5
4
3
2
1
West Yellowstone
Legend
Milepost Marker
Bridge
Study Area
Roads
1 0.5 0 1 Miles

4.3. Cost Benefit Analyses

For each mitigation measure the amount it must generate to reach the break-even point increases with the discount rate. The amortized annual costs were converted into threshold values (or break-even points) for bison-vehicle collisions per mile per year (Huijser, et al. 2009). A mitigation measure is considered economically feasible if the threshold value is exceeded by the mitigation site's average bison-vehicle collisions per mile per year.

Due to the sharp increase in BVCs per year starting in 2005, the cost-benefit analysis was performed using BVCs rates from 2005-2009. It is not clear to what the spike in BVCs is due, but the researchers hypothesize that a change in data collection methods was put into effect as of 2005. For the years 2005 through 2009, the average BVC rate was equal to 1.2 BVCs per mile per year (.75 BVCs per kilometer per year) for the Madison River mitigation site, and 0.4 BVCs per mile per year (.25 BVCs per kilometer per year) for the Duck Creek mitigation site.

4.3.1. Threshold Values for Madison River Site

Table 5 below gives the threshold values for each mitigation measure considered at the Madison River mitigation site for BVCs reported in 2005-2009. From this table it can be seen that all of the mitigation measures at a 3% discount rate, except for the overpass, elevated roadway and tunnel, are considered economically feasible as the threshold values are exceeded by the average rate of 1.2 BVCs per mile per year (.75 BVCs per kilometer per year).

4.3.2. Threshold Values for Duck Creek Site

Table 8 below gives the threshold values for each mitigation measure considered at the Duck Creek mitigation site for BVCs reported in 2005-2009. Except for seasonal signs, at a 3% discount rate these threshold values were not exceeded by the average BVC rate of 0.4 per mile per year for the Duck Creek site (.25 BVCs per kilometer per year).

Table 5: Madison River Mitigation Measures Using 1999-2009 Data

Threshold values (1999-2009)	Discount rate	Seasonal sign	Fence, gap, signs, crosswalk, jump-outs	Fence	Fence, underpass, jump-outs	Fence, overpass, jump-outs	ADS	Fence, gap, ADS, jumpouts	Elevated Roadway	Road tunnel
US$/mile/yr	1%	$120	11,182	$8,151	$16,359	$61,816	$36,503	$29,270	$1,720,306	$2,312,704
US$/mile/yr	3%	$130	13,941	$9,997	$23,415	$102,063	$38,298	$32,601	$2,172,234	$3,151,105
US$/mile/yr	7%	$156	20,682	$14,432	$41,072	$204,658	$42,967	$40,823	$3,369,755	$5,376,599
bison/mile/yr	1%	0.02	1.2	0.4	0.8	3.2	1.9	1.5	76.3	102.5
bison/mile/yr	3%	0.02	1.5	0.5	1.2	5.3	2.0	1.7	96.3	139.7
bison/mile/yr	7%	0.03	2.3	0.7	2.1	10.6	2.2	2.1	149.4	238.4

Table 6: Madison River Mitigation Measures Using 2005-2009 Data

Threshold values (2005-2009)	Discount rate	Seasonal sign	Fence, gap, signs, crosswalk, jump-outs	Fence	Fence, underpass, jump-outs	Fence, overpass, jump-outs	ADS	Fence, gap, ADS, jumpouts	Elevated Roadway	Road tunnel
US$/mile/yr	1%	$120	11,182	$8,151	$16,359	$61,816	$36,503	$29,270	$1,720,306	$2,312,704
US$/mile/yr	3%	$130	13,941	$9,997	$23,415	$102,063	$38,298	$32,601	$2,172,234	$3,151,105
US$/mile/yr	7%	$156	20,682	$14,432	$41,072	$204,658	$42,967	$40,823	$3,369,755	$5,376,599
bison/mile/yr	1%	0.01	0.7	0.2	0.5	1.9	1.1	0.9	44.5	59.8
bison/mile/yr	3%	0.01	0.9	0.3	0.7	3.1	1.1	1.0	56.2	81.5
bison/mile/yr	7%	0.02	1.3	0.4	1.2	6.2	1.3	1.2	87.1	139.0

Table 7: Duck Creek Mitigation Measures Using 1999-2009 Data

Threshold values (1999-2009)	Discount rate	Seasonal sign	Fence, gap, signs, crosswalk, jump-outs	Fence	Fence, underpass, jump-outs	Fence, overpass, jump-outs	ADS	Fence, gap, ADS, jumpouts	Elevated Roadway	Road tunnel
US$/mile/yr	1%	$120	11,182	$8,151	$16,359	$61,816	$36,503	$29,270	$1,720,306	$2,312,704
US$/mile/yr	3%	$130	13,941	$9,997	$23,415	$102,063	$38,298	$32,601	$2,172,234	$3,151,105
US$/mile/yr	7%	$156	20,682	$14,432	$41,072	$204,658	$42,967	$40,823	$3,369,755	$5,376,599
bison/mile/yr	1%	0.06	3.5	1.2	2.4	8.9	5.2	4.2	213.6	287.1
bison/mile/yr	3%	0.06	4.3	1.4	3.4	14.7	5.5	4.7	269.7	391.2
bison/mile/yr	7%	0.07	6.4	2.1	5.9	29.5	6.1	5.8	418.3	667.4

Table 8: Duck Creek Mitigation Measures Using 2005-2009 Data

Threshold values (2005-2009) (#BVC/mile/yr=	Discount rate	Seasonal sign	Fence, gap, signs, crosswalk, jump-outs	Fence	Fence, underpass, jump-outs	Fence, overpass, jump-outs	ADS	Fence, gap, ADS, jumpouts	Elevated Roadway	Road tunnel
US$/mile/yr	1%	$120	11,182	$8,151	$16,359	$61,816	$36,503	$29,270	$1,720,306	$2,312,704
US$/mile/yr	3%	$130	13,941	$9,997	$23,415	$102,063	$38,298	$32,601	$2,172,234	$3,151,105
US$/mile/yr	7%	$156	20,682	$14,432	$41,072	$204,658	$42,967	$40,823	$3,369,755	$5,376,599
bison/mile/yr	1%	0.04	2.2	0.7	1.5	5.6	3.3	2.6	133.5	179.4
bison/mile/yr	3%	0.04	2.7	0.9	2.1	9.2	3.4	2.9	168.5	244.5
bison/mile/yr	7%	0.05	4.0	1.3	3.7	18.5	3.8	3.6	261.4	417.1

4.4. Analysis of Stakeholder Survey Responses

A survey was distributed to over 40 different potential participants at 22 different stakeholder organizations. Unfortunately, the response level was very low. Only 11 participants fully or partially filled out the survey and returned it to the researchers. As shown in Figure 9, the representation by the participants of different types of organizations is very unbalanced, favoring NGOs. The represented non-governmental organizations are the Greater Yellowstone Coalition, Yellowstone Buffalo Foundation, Greater Yellowstone Conservation Association, Buffalo Field Campaign (2 participants), and the Defenders of Wildlife (2 participants). The represented natural resource management agencies are Yellowstone National Park Service, Gallatin National Park Service, and Montana Fish Wildlife and Parks (2 participants). There were no responses collected from governmental transportation or livestock agencies, nor from law enforcement. The low response level is attributed partially to the restricted time length of this study, the complexity (safety, ecological, economical, philosophical, and political aspects) combined with strong differences in opinion on how to deal with bison-vehicle collisions and their presence outside Yellowstone National Park, as well as the unavailability of participants due to summer field work and various other commitments.

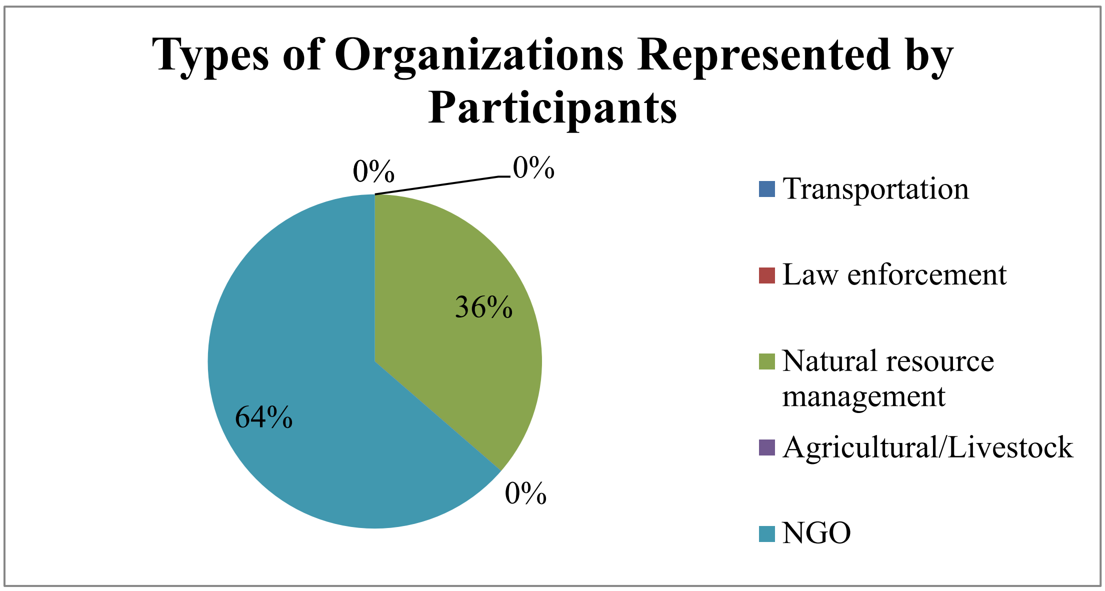


Figure 9: Question 2: How would you describe the type of the organization you work for?

4.4.1. Responses to Part I

Eleven participants responded to Part I of the survey, which consisted of 25 questions mainly addressed stakeholder opinions on the causes and solutions to BVCs. The crash and carcass removal data shows a drastic increase in annual BVCs from 2005 onwards (with the known exception of 2010, in which the BFC was mitigating the collisions).The survey responses shown in Figure 10 to the question on how BVCs on US 191 have progressed over the last 20 years support this trend in the data.

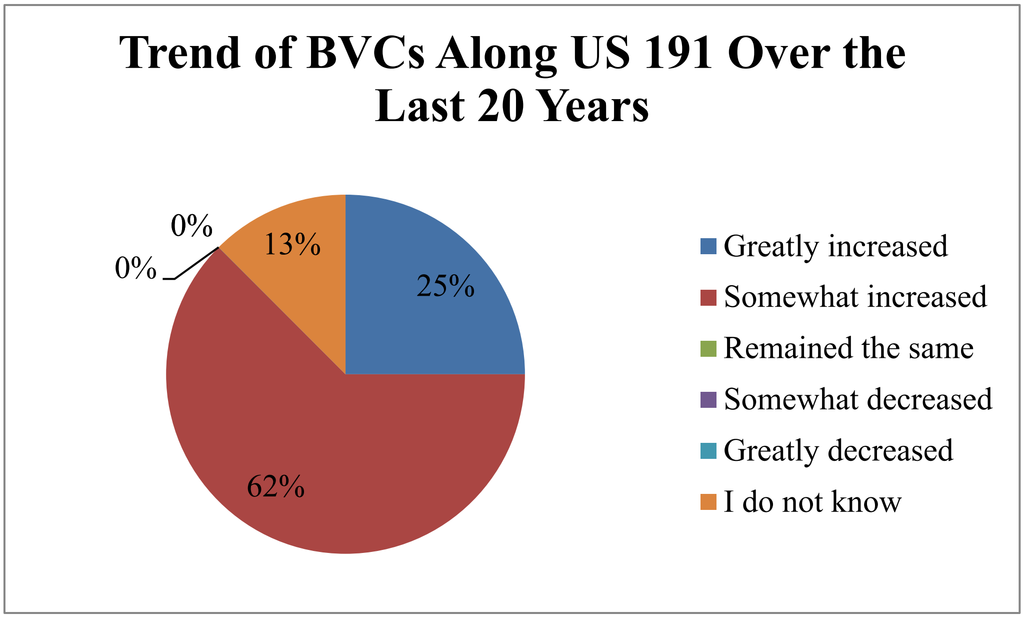


Figure 10: Question 4: Over the last 20 years, do you believe bison-vehicle collisions along US 191 have…?

Figure 11 shows the participants' opinions on the future of BVCs on US 191 for the next 5 years, assuming no mitigation measures are implemented. Survey response data, when paired with the temporal analysis of the crash and carcass removal data, suggest that BVCs on US 191 are a growing problem.

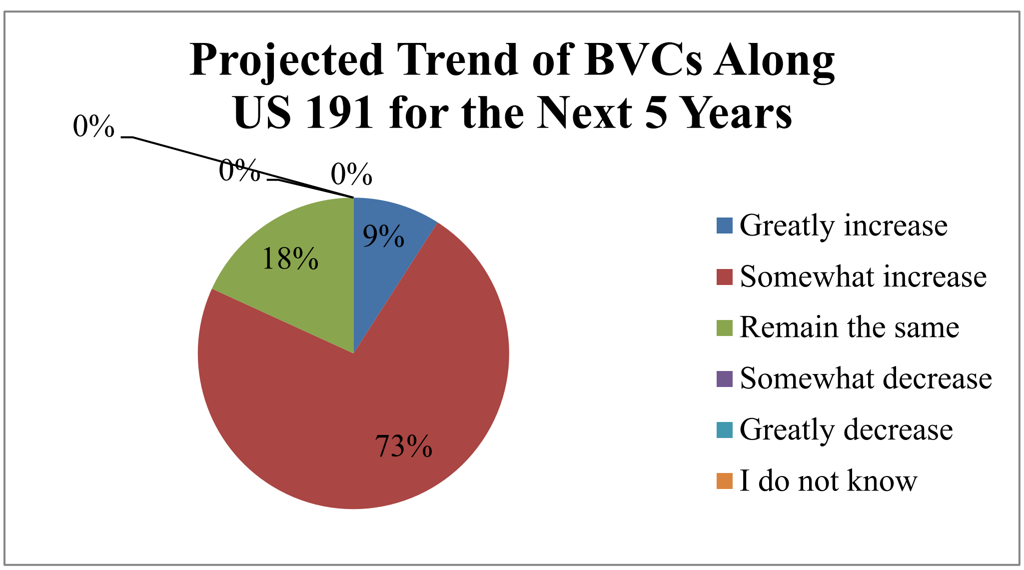


Figure 11: Question 11: How do you expect bison-vehicle collisions to evolve along U.S. Highway 191 and the West Yellowstone region over the next 5 years?

Survey participants were asked to select the leading potential causes of BVCs (Figure 12). Responses indicate that participants believe that poor visibility and speeding are the two most likely causes of BVCs. Poor visibility can be countered by roadside lighting. Speeding has already been partially addressed, as there is already a seasonal reduced maximum speed limit in place in the study site. However, survey responses to Question 12 (Appendix 2) suggest that this speed limit is not regularly observed. During an interview with a member of the BFC, whose members spend considerable time on US 191, it was learned that the stretch of US 191 between West Yellowstone and the park border apparently is not regularly patrolled by law enforcement.

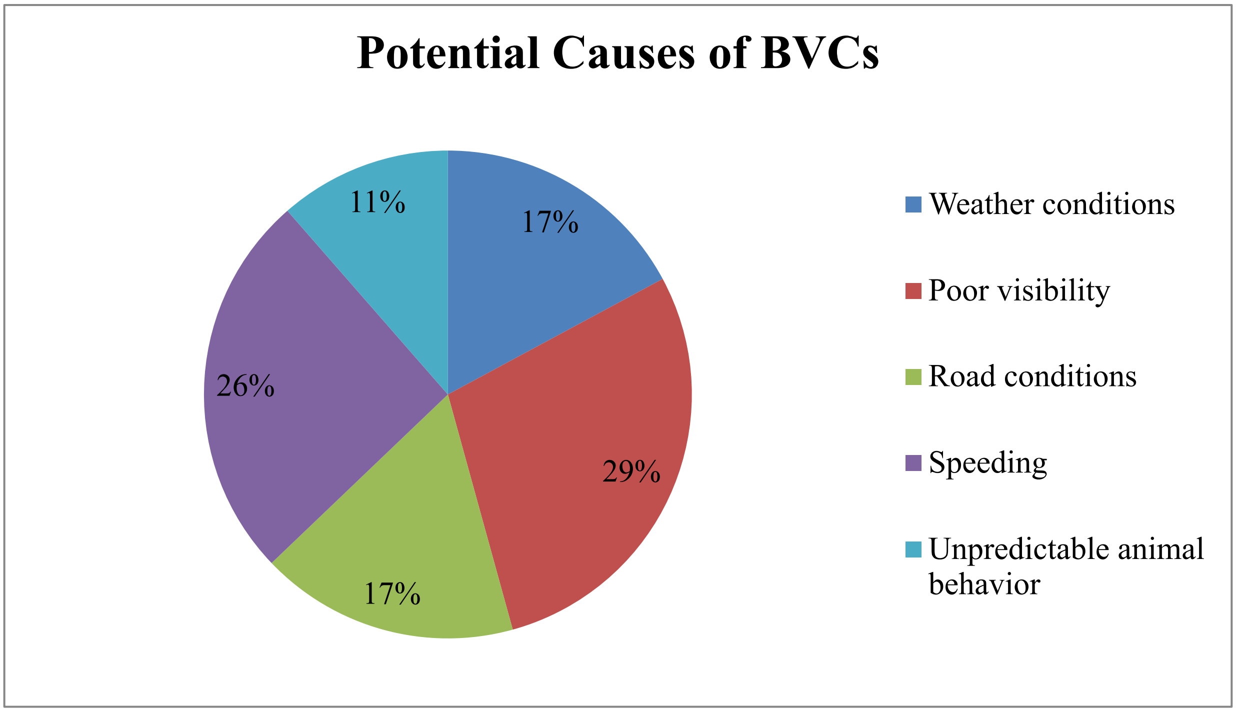


Figure 12: Question 18: What causes do you believe contribute most to bison-vehicle collisions on U.S. Highway 191 between West Yellowstone and Bozeman?

Survey participants were also asked to rate the potential effectiveness of possible mitigation measures (Figure 13). Wildlife fencing with safe crossing opportunities, maximum speed limit reduction, and public education and awareness were given the highest potential effectiveness rating, with wildlife warning signage closely following. It is interesting that public education and awareness and wildlife warning signage were given such high ratings, as studies have shown that these types of mitigation measures have very limited, if any, effectiveness at reducing WVCs.

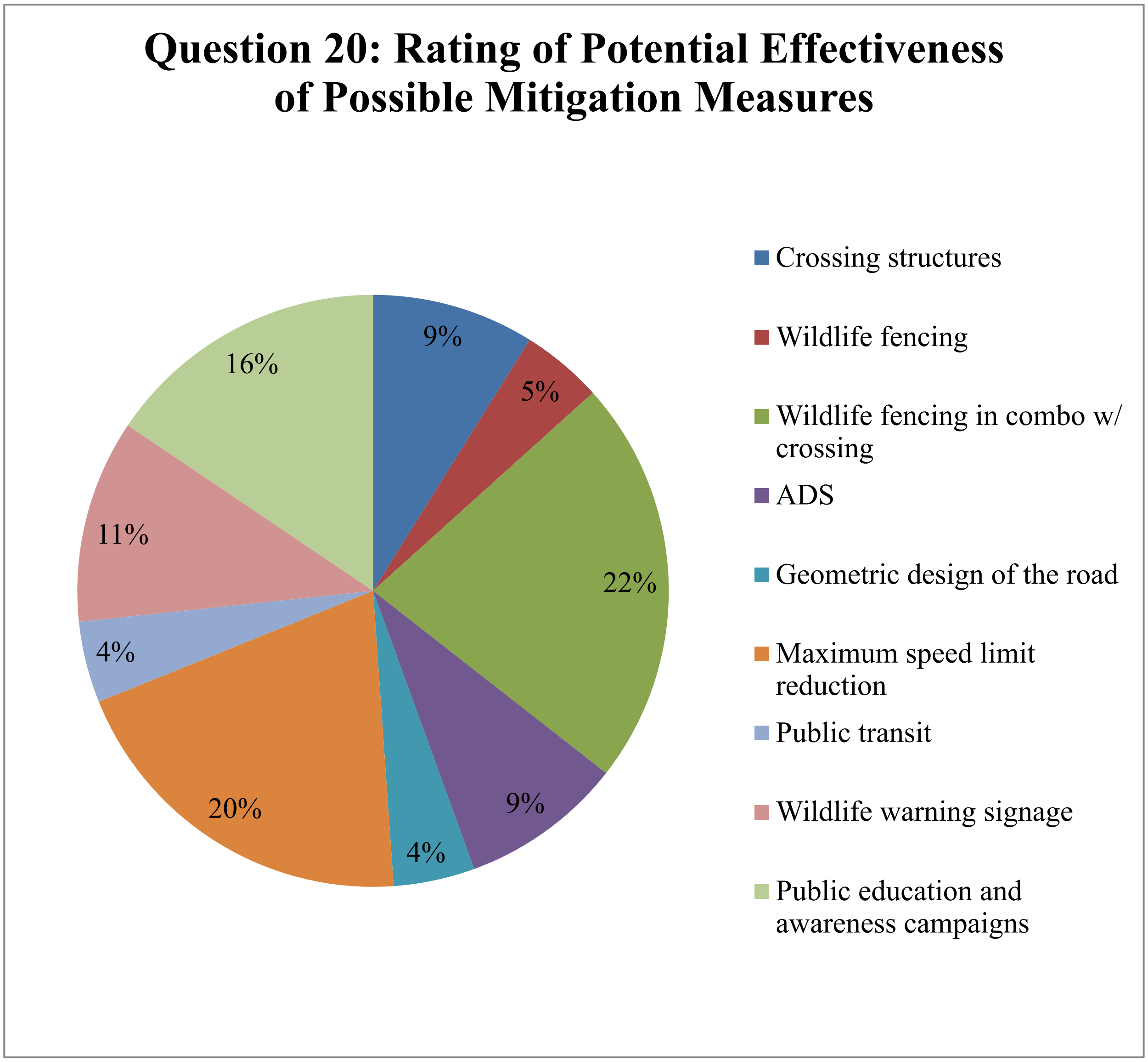


Figure 13: Question 20: What types of mitigation measures do you believe would be the most effective at reducing bison-vehicle collisions?

Finally, survey participants were asked where they believed mitigation funding should come from (Figure 14). Participants believed that federal agencies should bear the brunt of the costs. However, responses also held state agencies strongly accountable for funding. Responses for the category of "Other" sometimes included specifications such as Yellowstone National Park or National Park Service.

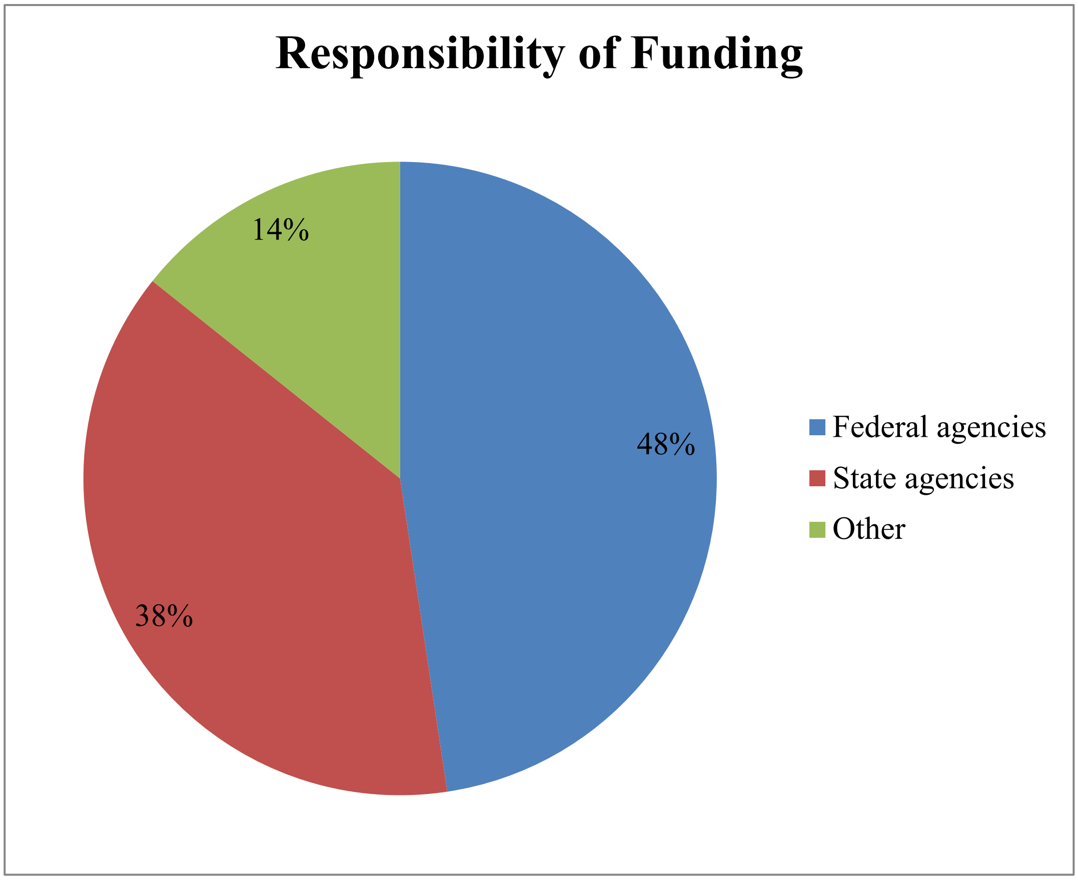


Figure 14: Question 25: Where should funding for measures aimed at reducing bison-vehicle collisions come from?

4.4.2. Responses to Part II

Of the 11 survey respondents, only 4 of them were able to answer questions in Part II. The participants for Yellowstone Buffalo Foundation and Montana Fish Wildlife and Parks responded to this section, as well as two participants from the Buffalo Field Campaign. Such a small sample size renders these responses. The researchers have therefore treated the information collected in Part II as information from subject experts.

4.4.2.1. Bison Behavior on US 191

The experts' responses to bison behavior along US 191 confirmed what the researchers had hypothesized based on background research on bison behavior and characteristics. Bison usually cross the highway in large groups, and take a long time (more than 3 minutes) to get completely across. Bison spend extended periods of time along the highway, both on the roadway itself or in the immediate vicinity. It was also confirmed that bison have very little reaction to vehicles. They either move off to the side of the roadway or do not move at all. A member of the BFC noted that occasionally bison are agitated by vehicles with noisy diesel engines, but do not necessarily leave the roadway.

4.4.2.2. Bison Management: Hazing Operations

It was originally hypothesized that the hazing operations of the IBMP were partially responsible for the levels and timing of the BVCs. This theory was not supported by information collected from experts. Interviews and survey responses suggest that while the hazing operations are not directly responsible for BVCs, the regular hazing of bison throughout the spring creates higher bison cross-traffic on US 191, as the bison often return from the hazing end points. However, this information may be biased. The researchers were not able to get in touch with representatives from the IBMP contributing agencies, and therefore do not have the input of the hazing operators. Further research is required on the interrelationship between hazing and BVCs.

4.5. Mitigation Recommendations

Based on BVC data for miles 1.0-10 on US 191, the researchers conclude that there are only two sites that have BVC levels make mitigation practical. The segment of miles 2.5-4.5 north of West Yellowstone has the highest level of BVCs. This segment of roadway straddles the Madison River and traditional bison migratory pathway. When considering the collision data for 2005-2009, this stretch of roadway shows a BVC rate of 2.4 collisions per year. The segment of roadway that has the second highest annual collision rate encompasses the Duck Creek migratory pathway, and covers miles 7.0 to 9.0 north of West Yellowstone. This stretch of US 191 has a BVC rate of .4 collisions per year when considering the data from 2005-2009. Recommendations for these two sites have been developed based on how closely the BVC rates justify the costs of mitigation, as well as conservation value of the bison and projected future of BVC on US 191. Survey responses were also used to identify other mitigation options for which a cost-benefit analysis was not performed.

4.5.1. Madison River Mitigation Site (Miles 2.5 to 4.5)

The Madison River and the surrounding terrain provide bison with an ideal travel corridor. It is used by bison annually as a migratory path from the high elevation grazing grounds of Yellowstone National Park to the lower elevation grazing and calving grounds of the West Yellowstone Basin. This means that the section of US 191 that cuts through this travel corridor has a high level of bison cross-traffic. Hundreds of bison each year cross US 191 on either side of the Madison River. South of the river, there is a high level of BVCs. North of the river there is a less severe level BVCs, however the researchers have learned through interviews that large herds of bison cross successfully at this point each year. The Madison River is also used as a hazing route by the IBMP. The following are mitigation recommendations for this site.

4.5.1.1. Overpass with Fencing and Jumpouts

The level of BVCs at the Madison River mitigation site does not justify the cost of an overpass with fencing and jumpouts. The threshold value of 3.1 collisions per mile per year was not met. However, the rate of 1.2 BVCs per mile per year (.75 BVCs per kilometer per year) for this segment is based on incomplete data. The cost attributed to a BVC is also very conservative due to the lack of available cost data. As further research is done in this area, the rate of collisions as well as the cost of collisions may increase. It is also important to consider the positive linear trend of BVCs. Based on the data for the past decade, the rate BVCs is projected to grow. It is possible that the threshold value of an overpass with fencing could be met within the near future. In addition, one should not use the results of the cost-benefit analyses as the sole determining factor in the mitigation measure decision process. The values given in this report are only estimates, and therefore have the potential to be wrong and changeable over time. Perhaps most importantly, the outcome of the cost-benefit analyses is dependent on what parameters were included and excluded. The current analysis is conservative and includes direct costs, but excludes passive use parameters.

It is also important to consider the fact that, while the rate of actual collisions for this segment does not justify an overpass, there is a large number of bison present each year that are not hit. The large amount of bison on and near the roadway can disrupt traffic flow, and could possibly pose a safety issue for non-vehicle human traffic such as snowmobilers and bicyclers. An overpass with fencing and jumpouts on this section of highway would reduce the level of BVCs and increase traffic flow, while preserving the migratory path of the bison.

While the threshold value for an underpass with fencing and jumpouts was met, the researchers were advised during interviews with various stakeholders that the ground surrounding the Madison River would be too wet for the bison to use. It is important to note that the bison generally travel on the ridges surrounding the Madison River, not along the riverbed itself, further suggesting that an underpass at the lowest sections would be far less suitable than an overpass that would be located on the North Bluffs of the Madison River, as shown in

Figure 15: North Bluffs of the Madison River seen from the south side of the river in the northbound lane

Photo by Isabella DiMambro

4.5.1.2. Animal Detection System (ADS) with Fencing and Jumpouts

The threshold value for this mitigation option was met for this segment of US 191. The cost of the mitigation measure would be regained in savings from reduction in BVCs in 75 years. Given the conservative cost of BVCs used in this study as well as the projected increase in the level of BVCs, this threshold value could possibly be met sooner. The effectiveness of this mitigation option is comparable to that of an overpass with fencing and jumpouts, and the cost is much less. However, it is important to note that an ADS does not remove the animals from the highway, but rather alerts motorists of their presence. This means that, regardless of the effectiveness of either measure at reducing BVCs, there is still the issue of bison presence affecting traffic flow that is solved by the overpass but not the ADS.

4.5.1.3. Seasonal Warning Signs and Speed Limit Enforcement

The threshold value for seasonal warning signs is easily met for this segment of US 191. They have also been shown to be effective when paired with the wildlife crossing efforts of the BFC. There are currently no bison warning signs on miles 2.5 to 4.5 north of West Yellowstone. A seasonal speed limit reduction to 55mph was put into effect several years ago due to the prevalence of BVCs on this stretch of highway. However, survey responses indicate that this speed limit is not observed nor enforced. Survey participants favored wildlife warning signage and speed limit reduction as potential mitigation measures. Based on the low cost and public support for signage and speed limit reduction, it is recommended that seasonal warning signs be implemented from February to June and that the current maximum speed limit reduction be enforced (the maximum speed limit reduction cannot be increased due to traffic safety restrictions). However, it is important to note that these mitigation measures have had very limited effectiveness in past studies.

4.5.2. Duck Creek Mitigation Site (Miles 7.0 to 9.0)

Duck Creek and the surrounding land is also a heavily used migratory path for bison. Due the close proximity to Yellowstone National Park as well as Gallatin National Forest, there is also a higher level of other wildlife species that cross US 191 than further south along the highway. Deer, elk, and moose crash and carcass data have shown that this is not only an area of concern for BVCs, but also for collisions with other large ungulates. It is also important to note that US 191 straddles grizzly bear habitat, and that there have been several grizzly bears hit on US 191 just a few miles north within the Yellowstone National Park border.

Just north of Duck Creek, Hwy 287 joins US 191. This creates unique challenges for mitigating this stretch of highway. Animals that have successfully crossed US 191 should not be fed into conflict with vehicles on Hwy 287. The following are mitigation recommendations for this site.

4.5.2.1. Animal Detection System with Fencing and Jumpouts

The BVC levels for this segment of US 191 do not meet the threshold values for an animal detection system with fencing and jumpouts. The level of BVCs on this segment does not economically justify any mitigation measures other than seasonal signage. As stated before, the BVC levels and cost of BVCs is very conservative and likely to change as further research is performed. The BVC levels are also projected to increase in future years. While the animal detection system with fencing and jumpouts is not immediately economically justifiable, the conservation value of the bison and other species such as deer, elk, moose, and grizzly bear

(*Ursus arctos horribilis*), make this segment of highway worthy of mitigation. The animal detection system with fencing and jumpouts is the mitigation measure whose threshold value is most closely met for this segment. Its effectiveness level is considerably higher than that of seasonal signage. The researchers believe this mitigation option to be the most effective based on cost versus effectiveness.

4.5.2.2. Seasonal Warning Signs and Speed Limit Enforcement

While the effectiveness of this mitigation measure is very limited, it is the only mitigation measure whose threshold value was met for this segment of roadway given the current BVC levels and cost value. Based on the economic factor as well as the positive responses for these mitigation measures given in the surveys, the researchers recommend seasonal warning signs be implemented and the speed limit be enforced.

There is a warning sign in billboard format directed at southbound traffic exiting the Yellowstone National Park border. However, this sign is set so far away from the side of the road as to be unnoticeable to a motorist, and it is in disrepair. The researchers were unable to determine who was responsible for the implementation of this sign.

5. CONCLUSIONS

Bison-vehicle collisions on US 191 pose a serious traffic safety threat each year. The purpose of this study was to provide mitigation recommendations to reduce the number of these collisions. Temporal analysis has shown BVCs are increasing on US 191. The conservative cost-benefit analysis has demonstrated that BVCs are also very costly. Background research and survey responses have revealed that there is considerable local interest in mitigating BVCs. Spatial analysis has identified two segments of roadway as mitigation sites.

The collision rates at the Madison River mitigation site (miles 2.5-4.5) make several mitigation options, including an ADS with fencing and jumpouts, economically feasible. The Madison River is a migratory path for bison, with hundreds of bison crossing US 191 each year within this road segment. The collisions that have occurred within the Madison River mitigation site make up 51% of the total collisions for the 10 mile study site on US 191 for the past decade. Mitigating this two mile road segment would address over half of the collisions.

The collision rates at the Duck Creek mitigation site (miles 7.0 to 9.0) identify this road segment as the second highest crash conflict zone. While the collision rates at this mitigation site do not economically justify any mitigation measures other than seasonal wildlife warning signage, mitigation at this site would still be valuable. Duck Creek is a bison migratory path as well as being habitat of other native species that are found in Yellowstone National Park and the Gallatin National Forest. The Duck Creek mitigation site has high conservation value. The collisions that have occurred within this road segment make up 17% of the total collisions for the 10 mile study site on US 191 for the past decade.

Based on the information available for this study, these are the researchers' current recommendations. Further research should be performed on the cost of an average BVC, as well as the effectiveness of lighting, vegetation management, and rumble strips at reducing large ungulate vehicle collisions, including bison. However, the temporal and spatial analyses performed in this study are accurate enough to have reliably identified BVCs as a growing concern, as well as the appropriate mitigation sites. This study can be used as decision support tool for BVC mitigation along US 191, as well as foundation research for future studies on BVCs in general.

6. APPENDIX

6.1. Appendix 1. Cost Estimates for Mitigation Measures

The estimated costs of the mitigation measures were based on the "Cost-Benefit Analyses of Mitigation Measures Aimed at Reducing Collisions with Large Ungulates in the United States and Canada: a Decision Support Tool" (Huijser et al 2009). Huijser (et al 2009) reported costs that were calculated for a motorway and standardized as costs (in 2007 US$) per kilometer road length. For this cost benefit analyses, costs were standardized as 2009 US$ per mile using U.S. Consumer Price Index (U.S. Department of Labor 2010) .

Seasonal wildlife warnings signs are designed to deliver a more time specific warning message to drivers and are only displayed during certain times of the year when the risk is much higher (Huijser et al 2008). Seasonal wildlife warning signs were estimated at US$1053 (in 2007 US$) per km, based on one sign and associated flashing lights installed per km per travel direction (large sign: US$400, 2 flashing lights: US$80) (Huijser et al 2009). For this cost benefit analyses, one sign and associated flashing light is assumed to be installed per mile per travel direction. The total cost was set at US$1,090 (in 2009 US$) per mile. The projected life span of the signs and warning lights were set at 10 years.

The purchasing costs for an ADS, including signs and power source or supply, were estimated at US$75,000 per km road length (in 2007 US$) (US$77,603 in 2009 US$ per mile) (both sides of the road) (Huijser et al 2009). However due to the ridges and landscape of the mitigation sites, the distance between sensors may be shorter, potentially resulting in cost increases. Huijser (et al 2009) estimated planning costs at US$50,000 in 2007 US$ (US$51,735 in 2009 US$ per mile), the installation costs were estimated at estimated at US$50,000 per km road length (US$51,735 in 2009 US$ per mile), maintenance and operations costs were estimated at US$14,800 per km per year (US$15,315 in 2009 US$). The projected life span of the system was set at 10 years, with system removal costs at the end of the life of the system estimated at US$10,000 per km (US$10,347 in 2009 US$) (Huijser et al 2009).

The costs for 2.4 m (8 ft) high wildlife fencing, including a dig barrier, was set at US$48 per m in 2007 US$, equal to US$96,000 per km road length for both sides of a road (in 2007 US$) (Huijser et al 2009). For this analyses the cost of wildlife fencing was converted to miles US$159,824 per mile road length (in 2009 US$). The projected life span of a wildlife fence was set at 25 years. The maintenance costs were set at US$500 per km per year (in 2007 US$), which was also converted to miles resulting in US$832 per mile per year (in 2009 US$). Fence removal costs were set at US$10,000 per km road length (US$10,347 in 2009 US$) (Huijser et al 2009).

The reported costs for a jump-out was estimated at US$9,813 (in 2007 US$) with a projected life span of 75 years). For this cost benefit analyses, jump-outs are set at US$ 10,154 (in 2009 US$).

The costs for purchasing one section of a break-the-beam animal detection system, including signs and power source or supply, were set at US$ 13,500 per km (in 2007 US$) (Huijser et al 2009). For our cost benefit analyses purchasing costs were set at US$ 13,968 per mile (in 2009 US$). The planning costs were estimated at US$ 25,000 (in 2007 US$) (US$25,868 per mile in 2009 US$); the installation costs were estimated at US$ 25,000 per km road length (US$25,868 per mile in 2009 US$); and maintenance and operation costs were estimated at US$ 11,800 per km per year (US$12,209 per mile per year in 2009 US$) (Huijser et al 2009). The projected life span of the signs and warning lights were set at 10 years. System removal costs were estimated at US$5,000 per km (US$5,174 per mile in 2009 US$). The width of the gap in the fence with the animal detection system was set at 100 m (328 ft), and it was not used to reduce the length of the fence. The costs for wildlife fencing was set at US$159,824 per mile, maintenance costs were set at US$832 per mile per year, and fence removal costs were set at US$ 10,347 per mile road length (all in 2009 US$). A jump-out was also provided every 317 m (1,040 ft) at US $49,065 per km in 2007 US$ (US$50,768 per mile in 2009 US$).

For the purposes of this cost benefit analyses for wildlife fencing in combination with wildlife underpasses, we provided a wildlife underpass for mitigation sites, which were equal to two-mile segments. This results in 1 underpass per 2 miles. The cost for an underpass was set at US$500,000, including materials and construction, planning costs were set at US$50,000 per structure, maintenance and operation costs were set at US$2,000 per structure per year (all in 2007 US$) (Huijser et al 2009). For this cost benefit analysis, the purchasing cost for an underpass was set at US$258,675 per mile; planning costs were estimated at US$25,868 per mile, maintenance and operation costs were estimated at US$1,035 per mile per year (all in 2009 US$). The projected life span of an underpass was set at 75 years. Structure removal costs were estimated at US$30,000 per structure (in 2007 US$) (US$10,347 per mile in 2009 US$). The length of the fence was not reduced due to the gap. The cost for wildlife fencing was set at US$159,824 per mile, fence maintenance costs were estimated at US$832 per mile per year, and fence removal costs were set at US$10,347 per mile road length (all in 2009 US$). The number of jump-outs between crossing structures was set at 7 per roadside per 2 miles (2 immediately next to a crossing structure (50 m on either side from the center of the structure), an additional five jump-out/ with 317 m (1,040 ft) intervals (7 per mile: US$71,075 per mile in 2009 US$).

For the purpose of our cost-benefit analyses for wildlife fencing in combination with wildlife overpasses, we provided a wildlife overpass for the mitigation sites, which were equal to two-mile segments. This results in 1 overpass per 2 miles. The cost for an overpass, including materials and construction, was set at US$5,000,000 per structure; planning costs were estimated at US$50,000 per structure; maintenance and operation costs were estimated at US$2,000 per structure per year (all in 2007 US$) (Huijser et al 2009). For this cost benefit analysis, the purchasing cost for an overpass was set at US$2,586,753 per mile; planning costs were estimated at US$25,868 per mile, maintenance and operation costs were estimated at US$1,035 per mile per year (all in 2009 US$). The projected life span of an overpass was set at 75 years. Removal costs of the structure was estimated at US$350,000 per structure in (2007 US$) (US$175,000 per mile in 2009 US$). Fencing and jump-outs costs were described in previous paragraphs.

The costs for an elevated roadway was set at US$60,000,000 per structure; planning costs were estimated at US$1,000,000 per km; maintenance and operation costs were estimated at US$1,000,000 per km per year (all in 2007 US$). The projected life span of an elevated roadway was set at 75 years. Structure removal costs were estimated at US$6,000,000 per km (in 2007 US$) (Huijser et al 2009). For this cost benefit analyses, purchasing costs were set at US$31,041,034 per mile, planning costs were estimated at US$1,034,701 per mile, maintenance and operation costs were estimated at US$1,034,701 per mile per year; and removal cost were estimated at US$3,104,103 per mile (all in 2009 US$).

The costs for a road tunnel was set at US$115,000,000 per km (in 2007 US$). The planning costs were estimated at US$1,000,000 per km (in 2007 US$). Maintenance and operation costs were estimated at US$1,000,000 per km per year (in 2007 US$) (Huijser et al 2009). The projected life span of an road tunnel was set at 75 years. Structure removal costs were estimated at US$11,500,000 per km. For this cost benefit analyses, purchasing costs were set at US$59,495,315 per mile, planning costs were estimated at US$1,034,701 per mile, maintenance and operation costs were estimated at US$1,034,701 per mile per year; and removal cost were estimated at US$11,899,063 per mile (all in 2009 US$).

6.2. Appendix 2: Stakeholder Survey

Bison-Vehicle Collisions on U.S. Highway 191 Between West Yellowstone and Bozeman

Survey

Western Transportation Institute

Montana State University

1. Which organization do you represent?

____

( ) I do not wish to answer this question

( ) I do not represent an organization

2. How would you describe the type of the organization you work for?

a) Transportation agency

b) Law enforcement agency

c) Natural resource management agency

d) Agricultural/livestock agency

e) Non-governmental organization

f) Other, please specify: ________________________________

g) I do not wish to answer this question

3. How many years of experience or knowledge do you have with regard to the bison-vehicle collisions on U.S. Highway 191 between West Yellowstone and Bozeman?

a) less than or equal to 1 year

b) 2-5 years

c) 6-10 years

d) 11 years or more

e) I do not wish to answer this question

4. Does your organization collect any data concerning these bison-vehicle collisions?

a) Yes.

Please describe: ____

Can we obtain access to this data for this project? Yes / No

b) No.

c) I do not know

d) I do not wish to answer this question

5. In your experience, on which road section do most of the bison-vehicle collisions occur?

a) Between West Yellowstone and the Junction with Highway 287,

Please specify____

b) Between the Junction with Highway 287 and Big Sky,

Please specify____

c) Between Big Sky and Bozeman:

Please specify____

d) I do not know

e) I do not wish to answer this question

6. Do you collect any data concerning bison movements?

a) Yes.

Please Describe: ____

Can we obtain access to this data for this project? Yes / No

b) No.

c) I do not know

d) I do not wish to answer this question

7. How would you characterize the existing road system and road capacity (or level of service) on US Highway 191between West Yellowstone and Bozeman?

a) Below capacity

b) At capacity

c) Over capacity

d) I do not know

e) I do not wish to answer this question

8. Over the next 10 years, do you project the traffic volume on U.S. Hwy 191 between West Yellowstone and Big Sky to:

a) Increase

b) Remain level

c) Decrease

d) I do not know

e) I do not wish to answer this question

9. Over the last 20 years, do you believe bison-vehicle collisions along US Hwy 191 have:

a) Greatly increased
b) Somewhat increased
c) Remained the same
d) Somewhat decreased
e) Greatly decreased
f) I do not know
g) I do not wish to answer this question

10. Over the last 20 years, do you believe bison presence along US Hwy 191 has:

a) Greatly increased
b) Somewhat increased
c) Remained the same
d) Somewhat decreased
e) Greatly decreased
f) I do not know
g) I do not wish to answer this question

11. How do you expect bison-vehicle collisions to evolve along U.S. Highway 191 and the West Yellowstone region over the next 5 years?

a) Strongly increase
b) Increase
c) Stay level
d) Decrease
e) Strongly decrease
f) I do not know
g) I do not wish to answer this question

12. In your experience, do drivers generally follow the posted maximum speed limits on U.S. Highway 191 between West Yellowstone and the Junction with U.S. Highway 287?

a) Yes, to a large extent
b) Yes, to some extent
c) Not usually

d) Almost never

e) I do not know

f) I do not wish to answer this question

13. How important are the following (potential) angles of bison management to you:

Rate all that apply	Scale 1 = lowest; 5 is highest
Traffic safety	1 2 3 4 5 (circle one number)
Agriculture/livestock	1 2 3 4 5 (circle one number)
Conservation status including ecological integrity	1 2 3 4 5 (circle one number)
Other, please specify:_____________________	1 2 3 4 5 (circle one number)

14. Please rate the importance of each factor with regard to reducing bison-vehicle collisions:

Rate all that apply	Scale 1 = lowest; 5 is highest
Reducing bison-vehicle collisions	1 2 3 4 5 (circle one number)
Reducing barriers in the landscape for bison (incl. roads)	1 2 3 4 5 (circle one number)
Maintaining traffic flow	1 2 3 4 5 (circle one number)
Limiting the cost of potential mitigation measures	1 2 3 4 5 (circle one number)
Speedy implementation of mitigation measures	1 2 3 4 5 (circle one number)
Public awareness of bison-vehicle collisions	1 2 3 4 5 (circle one number)

Other, please specify _________________________	1 2 3 4 5 (circle one number)

15. What are your feelings towards bison migrating outside of Yellowstone Park?

a) Major concern (please specify): ______________________________________
b) Minor concern (please specify): ______________________________________
c) Neutral
d) Positive occurrence (please specify): ___________________________________
e) Very positive occurrence (please specify): _______________________________
f) I do not know
g) I do not wish to answer this question

16. How do you expect attempted bison movements outside of Yellowstone National Park to evolve over the next 5 years?

a) Strongly increase
b) Increase
c) Stay level
d) Decrease
e) Strongly decrease
f) I do not know
g) I do not wish to answer this question

17. Please rate the following issues that may affect the bison population by level of impact (based on your opinion):

Rate all that apply	Scale 1 = lowest; 5 is highest

Road mortality	1 2 3 4 5 (circle one number)
Habitat fragmentation	1 2 3 4 5 (circle one number)
Hunting	1 2 3 4 5 (circle one number)
Increase danger/risk to visitors (and consequently bison)	1 2 3 4 5 (circle one number)
Habitat loss	1 2 3 4 5 (circle one number)
Other, please specify:____________________	1 2 3 4 5 (circle one number)

18. What causes do you believe contribute most to bison-vehicle collisions on U.S. Highway 191 between West Yellowstone and Bozeman? (Circle all that apply).

a) Weather conditions
b) Poor visibility (e.g. during the night)
c) Road conditions
d) Speeding
e) Unpredictable animal behavior
f) Other (Please specify): ________________________________

19. What types of mitigation measures do you believe would be considered good practice (regardless of how effective they may be in reducing bison-vehicle collisions)?

Circle all that apply
a) Crossing structures (over- and underpasses for wildlife)
b) Wildlife fencing
c) Wildlife fencing in combination with safe crossing opportunities for wildlife
d) Animal detection systems
e) Geometric design of the road
f) Maximum speed limit reduction
g) Public transit (shuttle buses, light rail, etc.)
h) Wildlife warning signage
i) Public education and awareness campaigns
j) Other (Please specify): ____________________________________
h) I do not know
i) I do not wish to answer this question

20. What types of mitigation measures do you believe would be the most effective for reducing bison-vehicle collisions?

Circle all that apply
a) Crossing structures (over- and underpasses for wildlife)
b) Wildlife fencing
c) Wildlife fencing in combination with safe crossing opportunities for wildlife

d) Animal detection systems
e) Geometric design of the road
f) Maximum speed limit reduction
g) Public transit (shuttle buses, light rail, etc.)
h) Wildlife warning signage
i) Public education and awareness campaigns
j) Other (Please specify): ____________________________________
h) I do not know
i) I do not wish to answer this question

21. Why do you believe these mitigation measure(s) would be most effective?

____
____

22. What do you see as potential solutions that may be acceptable to all stakeholders with regard to bison-vehicle collisions?

Circle all that apply
a) Crossing structures (over- and underpasses for wildlife)
b) Wildlife fencing
c) Wildlife fencing in combination with safe crossing opportunities for wildlife
d) Animal detection systems
e) Geometric design of the road
f) Maximum speed limit reduction
g) Public transit (shuttle buses, light rail, etc.)
h) Wildlife warning signage
i) Public education and awareness campaigns
j) Other (Please specify): ____
h) I do not know
i) I do not wish to answer this question

23. What do you see as the biggest obstacle in implementing mitigation measures aimed at reducing bison-vehicle collisions on U.S. Highway 191 between West Yellowstone and Bozeman?

Circle one
a) Collisions not predictable enough in space or time
b) Insufficient funding for mitigation measures
c) Limited ability of stakeholders to work together and implement mitigation measures
d) Other (please specify): ____
e) I do not know

f) I do not wish to answer this question

24. What do you think is required of the stakeholders to make progress in implementing mitigation measures aimed at reducing the bison-vehicle collisions?

____

25. Where should funding for measures aimed at reducing bison-vehicle collisions come from?

a) Federal agencies (please specify): ____
b) State agencies (please specify): ____
c) Other (please specify): ____
d) I do not know
e) I do not wish to answer this question

IF YOU ARE INVOLVED IN THE HANDLING, OBSERVATION, OR DIRECT MANAGEMENT OF BISON, PLEASE CONTINUE TO PART II.

24. Is there anything else you would like to share with regard to bison-vehicle collisions on U.S. Highway 191 between west Yellowstone and Bozeman?

____
____
____
____

Many thanks for participating in this survey, it is much appreciated!

We will contact you to schedule an interview in person or over the phone.

You may also choose to fill out this survey and send it to:

Marcel P. Huijser, PhD
Research Ecologist, Road Ecology Program
Western Transportation Institute (WTI) - Montana State University (MSU)
PO Box 174250, Bozeman, MT 59717-4250
Phone: (406) 543-2377, Fax: (406) 994 1697, e-mail: mhuijser@coe.montana.edu

PART II

Bison Behavior Along US Hwy 191 and Bison Management

1. Are there sections along Hwy 191 where bison have been known to cross successfully?
    a) Yes (Please specify): ____
    b) No
    c) I do not know
    d) I do not wish to answer this question

2. How many bison, on average, cross the highway at a time?
    a) One bison
    b) 2-4 bison
    c) >4 bison
    d) I do not know
    e) I do not wish to answer this question

3. How long would you say it takes an individual bison to cross the highway, on average?
    a) Less than a minute
    b) Between one and three minutes
    c) More than three minutes
    d) I do not know
    e) I do not wish to answer this question

4. How long would you say it takes a herd of bison to cross the highway, on average?
    a) Less than a minute
    b) Between one and three minutes
    c) More than three minutes
    d) I do not know
    e) I do not wish to answer this question

5. Do they spend long (>10 minutes) stretches of time along Hwy 191?

a) Yes
b) No
c) I do not know
d) I do not wish to answer this question

6. How do the bison react to vehicles?
   a) Retreat from the vicinity of the highway at the approach of vehicles
   b) Move off the highway itself but stay along the sides or near by
   c) Do not react to vehicles, remain on highway
   d) I do not know
   e) I do not wish to answer this question

7. Besides bison-vehicle collisions, do you believe bison significantly affect traffic on Hwy 191?
   a) Yes, to a large degree (Please specify): ______________________________________
   b) Yes, to a small degree (Please specify): ______________________________________
   c) Neutral
   d) No, definitely not
   e) I do not know
   f) I do not wish to answer this question

8. In the spring, when do official hazing runs start?

____

9. How effective is the hazing procedure at keeping the bison together?
   a) Very effective
   b) Moderately effective
   c) Not very effective
   d) Not effective at all
   e) I do not know
   f) I do not wish to answer this question

10. How are stragglers or bison that split-off from the herd dealt with during hazing?
   a) Capture
   b) Culling

c) Hazed back into the herd
d) They are not dealt with
e) I do not know
f) I do not wish to answer this question

11. To what degree do you believe there is unofficial hazing (outside of official time frame, hazing by individual ranchers, etc.)?

a) To a large degree
b) To a small degree
c) I do not believe there is any unofficial hazing
d) I do not know
e) I do not wish to answer this question

12. If you do believe there is unofficial hazing, would you please describe the process, including such information as when and roughly where:

____

____

13. Are the bison controlled as they begin to journey outside of the Yellowstone National Park borders?

a) Yes (Please specify season and area): ____

____
b) No
c) I do not know
d) I do not wish to answer this question

14. Is there anything else you would like to share with regard to bison-vehicle collisions on U.S. Highway 191 between west Yellowstone and Bozeman?

____

____

____

____

Many thanks for participating in this survey, it is much appreciated!

We will contact you to schedule an interview in person or over the phone.

You may also choose to fill out this survey and send it to:

Marcel P. Huijser, PhD
Research Ecologist, Road Ecology Program

Western Transportation Institute (WTI) - Montana State University (MSU)
PO Box 174250, Bozeman, MT 59717-4250
Phone: (406) 543-2377, Fax: (406) 994 1697, e-mail: mhuijser@coe.montana.edu

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